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NATURALE SPECIES RATIOQUE

MADISON, WISCONSIN
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CHANCEY JUDAY,

Secretary.

CONTENTS

THE ROMANTICISM OF EDWARD YOUNG

HARRY HAYDEN CLARK

The object of the present study is to supply a concise and reasonably comprehensive exposition of Edward Young's kinship with the Romantic Movement. Although it has been said that he is "scarcely to be reckoned among the romanticists,"[1] that he made "no real contribution to the new feeling for nature,"[2] and that he belongs to the "traditional school" of those who "reacted" against early romantic tendencies,[3] recent studies of the rise of isolated romantic traits suggest that Edward Young is perhaps worthy of renewed study as an early romanticist. In particular, one striking paradox appears to have escaped attention: what accounts for the phenomenal popularity of this supposedly ultra-conservative religious poet in an age of increasing radicalism? In order to ascertain in what ways Young is romantic I propose simply to discover which of his doctrines he held in common with those later nineteenth century writers generally referred to as romanticists. This method will be safer, I think, than an attempt to measure him by any one artificial definition of romanticism.[4] Since it happens that some of these doctrines are among the less admirable contributions of romanticism, occasional references to the greater figures may seem a bit unsympathetic; it may not be amiss to remark at the outset, therefore, that our concern with them is limited to a consideration of points where their thought chances to be tangent to that of Young, that it is obviously impossible here to do justice to the many-sided genius of such men as Wordsworth, Shelley and Keats.

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[1] H. A. Beers, *A History of English Romanticism in the Eighteenth Century*, N. Y., 1898, p. 163.

[2] Myra Reynolds, *The Treatment of Nature in English Poetry*, Chicago, 1909, p. 121.

[3] Ernest Bernbaum, *English Poets of the Eighteenth Century*, N. Y., 1918, p. xxvi.

[4] On the ambiguities of the term "romanticism" see A. J. Lovejoy, "The Discriminations of Romanticisms," *PMLA*, XXXIX, 299ff., and Paul Kaufman, "Defining Romanticism: A Survey and a Program," *MLN*, XL, No. 4.

I

What first impresses the reader of Young's major work is his dissatisfaction with actual life. We must remember that his early life was thoroughly worldly. Although he seems to have kept his Oxford chambers at All Souls until he became the rector of Welwyn at the age of forty-seven, he often attended Addison's "little senate" at Button's coffee-house in Queen Anne's London; one of the "Wits," he was the friend of Steele, Carey, Budgell, Tickell, Pope, old Cibber and the profligate Wharton. All his early work, culminating in the seven satires composing *The Love of Fame* (1725), was dedicated, with fulsome flattery, to various people of high station in the vain hope of obtaining court preferment. As a dramatist, the author of the three tragedies *Busiris* (1719), *The Revenge* (1721), and *The Brothers* (written in 1726, but withheld until 1753), he had been only moderately successful. He had been defeated as a candidate for the House of Commons in 1722.[5] Having exhausted the possibilities of worldly success, he took Holy Orders in 1727, and in 1731—after ceaseless efforts—he accepted the living of a country clergyman at Welwyn. Ambitious and proud, Young seems to have felt himself unjustly neglected; he became a man with a grievance. And he apparently secured a sort of psychological revenge by embracing what purports to be a religious other-worldliness. Generally an extremist, he believed a choice must be made between this world and the "next."

> "Religion's all. Descending from the skies
> To wretched man, the goddess in her left
> Holds out this world, and in her right the next."[6]

. . .

> "The Visible and Present are for brutes,
> A slender portion, and a narrow bound!
> These Reason, with an energy divine,
> O'erleaps, and claims the Future and Unseen;
> The vast Unseen, the Future fathomless![7]

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[5] H. C. Shelley, *Life and Letters of Edward Young,* London, 1914. p. 61.
[6] *Night Thoughts,* (hereafter referred to as *N. T.*) IV, 550ff.
[7] *N. T.,* VI, 246–250.

His attitude toward the here and now is clear; he calls it this "miry vale"[8]; "this nest of pains"[9]; "this dark, incarcerating colony"[10]; "this night of frailty, change, and death"[11]; "this dismal scene"[12]; this "vapour"[13]; this "prison"[14]; this "pestilential earth"[15]. No wonder he longed to escape to "that vast Unseen!"

This attitude toward the actual world was the groundwork of much of the later romantic idealism. It is interesting to find it predominating in Germany,—where Young's influence was strongest—as illustrated in the phantasies of Tieck and Novalis. Shelley in his Dedication of *The Cenci* tells us this "fearful and monstrous" story is unique among his works in being "a sad reality," while his writings "hitherto published" are "dreams of what ought to be, or what may be." The arch-romantic American James Branch Cabell—to whom "veracity is the one unpardonable sin"—"perceives this race . . . to be beyond all wording petty and ineffectual," and he follows " the instinct of any hurt animal to seek revenge. . . in the field of imagination" by retreating to Poictesme, "that fair country . . . which is bounded by Avalon and Phaeacia and Sea-coast Bohemia, and the contiguous forests of Arden and Broceliande, and on the west of course by the Hesperides." Keats longs to escape "on the viewless wings of Poesy" from

> "The weariness, the fever and the fret
> Here, where men sit and hear each other groan,"

to the

> "Charmed magic casements, opening on the foam
> Of perilous seas, in faery lands forlorn."

All this obviously stands in sharp contrast to the vigorous interest in contemporary problems manifested by the neo-classic Defoe, Swift, Addison and Steele. It also contrasts

[8] *N. T.*, IV, 537.
[9] *Ibid.*, III, 409.
[10] *Ibid.*, IV, 665.
[11] *Ibid.*, IV, 555.
[12] *Ibid.*, III, 363.
[13] *Ibid.*, VIII, 138.
[14] *Ibid.*, IX, 1019.
[15] *Ibid.*, IX, 1352.

with the Greek objective which has been defined as "a serious endeavor to understand the world and man, having for its chief aim the discovery of the right way of life and the conversion of people to it."[16] The heroes of antiquity were essentially men of the senses and the understanding. Dante, on the other hand, records the passing of man from the world of sense to that of spirit; in other words his moral conversion. And in Cervantes there follows what was almost inevitable,—the perpetual contradiction between the spiritual and the natural man in actual life. Conscious, as they were, of the gap between the ideal and the real, many of the romanticists turned their back upon the real and, like Young, became enamoured of "the vast Unseen, the Future fathomless."

In the case of Young, we are led to seek the cause of his contempt for the world. In his personal life he met with considerable grief and disillusionment; his wife died in the prime of life, and "he never obtained the preferment of which he thought himself entitled."[17] However, I am inclined to think that the real source of his disdain for the "Visible and Present" is to be found in his conception of original genius, emphasizing, as it does, the quest of novelty. He has been expostulating with Lorenzo upon the shocking thought of a continued existence on earth, when he concludes:

> " . . . With laboring step
> To tread our former footsteps? pace the round
> Eternal? to climb life's worn, heavy wheel,
> Which draws up nothing new? to beat, and beat
> The beaten track? to bid each wretched day
> The former mock? to surfeit on the same,
> And yawn our joys? or thank a misery
> For change, though sad?"[18]

It is evident here as elsewhere that *ennui* resulting from an unsuccessful quest for novelty tends to mould his view of life: he longs for what is new and distinctive. These are a few of the reasons why he sought consolation in solitude.

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[16] See J. Burnet's *The Legacy of Greece* p. 58, where this is said to be the dominating spirit of Greek philosophy.

[17] Sir Leslie Stephen, *Dictionary of National Biography,* XXI, 1285.

[18] *N. T.,* III, 329–36.

II

The importance of solitude in the romantic movement has been stressed many times, and it has been brilliantly demonstrated that solitude is not far from the core of the whole romantic philosophy.[19] Speaking in social terms, the most classic person is the Greek citizen in the agora merging his personality into the life of the state; the most romantic, the hermit. It is quite fitting that Petrarch, usually recognized as the first modern man, should have been a lover and praiser of solitude. Wordsworth "wandered lonely as a cloud" amid the silent scenes of nature; solitude made him a poet. The disillusioned author of *Alastor* fled away from man and all his works; he found a symbolic meaning in the desolate mountain peaks and the open unoared sea. The insolence of egotism isolated *Childe Harold* from his fellows, while across the channel his brother *René* bemoaned the "moral solitude" so characteristic of romanticism.

In the case of Young's later life this isolation is marked indeed. When he praises night he means solitude, for in his nocturnal habits he finds a double solitude,—both physical and moral. The darkness, of course, separates him from his fellows, but probably he enjoyed much more than this the thought which he expresses as follows:

> "Let Indians and the gay, like Indians, fond
> Of feathered fopperies, the sun adore;
> Darkness has more divinity for me."[20]

He loved to think that there was something distinctive—and therefore superior—in his midnight watches. Doubtless his desire to be distinctive in this way sprang from his theory of original genius, again, and suggested his love of solitude. Furthermore, in his praise of night we have an example of his choice of melancholy suggestion,—he preferred night to day because, among other advantages, it was more melancholy,

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[19] Cf. Professor Odell Shepard's doctoral dissertation on *Solitude considered as One Phase of the Romantic Movement,* Harvard, 1916, to which I am indebted for several suggestions.

[20] *N. T.,* V, 126–128.

"How like a widow in her weeds, the night,
Amid her glimmering tapers, silent sits!
How sorrowful, how desolate, she weeps
Perpetual dews, and saddens nature's scenes!"[21]

Two other reasons may be given to account for his love of solitude, both of which carried much weight with the later romanticists. First, Young thinks that solitude nourishes virtue.

"Virtue, for ever frail as fair below,
Her tender nature suffers in the crowd,
Nor touches in the world without a stain;
The world's infectious."[22]

Here we have the germs of a doctrine which was later to deny the struggle between good and evil within the breast of the individual and assert that every evil thing comes from without, from social institutions. Young, however, did not accept any such fallacy. In his love of solitude, however, he is certainly gravitating toward the later romantic extreme. The second reason why he is so "studious of sequestered scenes" is that he thinks solitude inspires wisdom, —wisdom of the unearthly, ecstatic sort which ends in melancholy.

"O sacred solitude! divine retreat!
Choice of the prudent! Envy of the great!
By thy pure stream, or in the wavy shade,
We court fair wisdom, that celestial maid . . . "[23]

This conception is clearly related to his nature cult which we shall have occasion to study later. On close examination, however, it is evident that this solitary communion with nature is but a disguised form of his disdain of this world and an excuse to escape on the viewless wings of his imagination.

" . . . I bless Night's consecrating shades,
Which to a temple turn a universe,
Fill us with great ideas full of heaven,
And antidote this pestilential earth."[24]

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[21] *N. T.*, IX, 1978–81.
[22] *Ibid.*, V, 139–142.
[23] *Love of Fame*, Satire V, 255–58.
[24] *N. T.*, IX. 1849–53.

III

Perhaps Young's conception of the imagination is his most fruitful contribution to the romantic movement. If one distinction between the classic and romantic is to be found in the different rôle of the imagination in each, then we are justified in an attempt to determine the precise quality of Young's imagination.

In an endeavor to do what is almost impossible, to explain the classic conception of the imagination, one may refer to Plato's somewhat enigmatic theory of the "Ideas". The "Idea" was a mental concept which embodied the essence of the class of sense-objects under consideration; it was the ultimate reality; it was the perfection, of which all things perceived by the senses were but imperfect copies. The object of classic art was to reproduce this "Idea", to derive the universal from the particular. It should be observed that this is a process essentially creative and imaginative; it is based on actual reality, but is selects only the representative aspects of that reality. The classic artist examined many models, selected the one or two more perfect fragments of each, and then by imagination assembled these perfect fragments into a perfect whole, a masterpiece of his imagination; then, holding this vision of perfection, this "Idea", before his mind's eye, he imitated it with his pen or brush. A program such as this involves the very highest exercise of imagination and imitation. It is the imitation of what has no visible existence; it is something like trying to retell our purest dreams. Classic art is ideal; accepting the view that sense-objects are but faulty copies of the "Idea", the artist seeks to correct this imperfection. Someone has said that nature is a great artist whose hand trembles; classic art, as the neo-classic Sir Joshua Reynolds puts it, "strives to supply the natural imperfection of things, and often to gratify the mind by realizing and embodying what never existed but in the imagination."[25]

Of romanticism, one must remember, there are at least three varieties. The first variety of romanticism—a romanticism of action, the Quixotic type—germinated in the

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[25] *Fifteen Discourses on Art.*

medieval romances; the imagination sought fictitious adventure of an extravagant sort, as in *Aucassin and Nicolette.* The Renaissance strove to recover the classical imagination from the oblivion into which it had fallen, but the pendulum soon swung again to the second variety of romanticism, a romanticism of thought, usually associated with Donne and the "metaphysical school". Poetry pursued thought down all its fantastic paths to its furthest ramifications; the milestones which marked the limits of the normal and typical were coolly ignored. This quest of the singular and novel brought forth from Doctor Johnson the charge that the "grandeur of generality" was lost, and straightway the "understanding age" ostracized imagination as being germane to the metaphysical malady and deified reason in the Temple of Taste. The delicate balance which Aristotle had maintained between imagination and reason was upset; his theory of imitation became misinterpreted to mean imitation of outer models, and allegiance to an elaborate system of rules based on these models was required of all artists. The imagination was discredited from all sides: Descartes and Bacon had attacked it in the name of logic; Spinoza in the name of Stoical reason; Locke, Hartley, and Hume in the name of analysis; and Boileau and Pope attack in the name of good senses. Hobbes identifies the imagination with the memory of actual outer images, and so calls it "decaying sense". An index to the situation is given us by Addison, in his papers on *The Pleasures of the Imagination* when he limits his discussion to images produced by the sense of sight alone. The point to observe is that the imagination of the neo-classic period always clung close to reality—what had existed, or at least what might exist. Thus there came a revolt—not against Aristotle and true classicism—but against the false interpreters of classicism. Human nature could not brook having emotion and imagination in such servile bondage to reason, and a revolt began in what we know as the third variety of romanticism,—a romanticism of feeling. All three varieties, let us notice, have a common denominator: the quest of the strange, the remote, the unique, as opposed to the normal, the immediate, the representative.

Among those who helped to liberate the imagination, chief mention should be made of Akenside whose *Pleasures of the Imagination* (begun in 1738, although the first versions were not published until 1744) supplied aesthetic theory for romantic practice. Here we find a disdain for the familiar and the commonplace, in connection with an indefinite, aimless, expansive longing, a homesickness for the infinite.

"Where does the soul
Consent her soaring fancy[26] to restrain . . . ?
. . . The rich earth
Cannot contain her; nor the ambient air . . .
. . . The highborn soul
Disdains to rest her heaven-aspiring wing
Beneath its native quarry. Tired of earth
And this diurnal scene, she springs aloft
Through fields of air . . .
Even on the barriers of the world, untired
She meditates the eternal depth below."

As the eighteenth century wore on even the exponents of academic culture exalted imagination above reason. As early as 1756 Joseph Warton startled the strongholds of criticism with the declaration that the work of Pope was "not of the most poetic species of poetry . . . because his imagination was not his predominant talent". And it is a striking fact that the first use of the phrase "creative imagination" occurs in the same author's dedication to the *Essay on the Genius and Writings of Pope.*[27] The function of the imagination had changed from that of mental photography based on actual reality to that of creation. And this early exaltation of the creation imagination was strongly advocated by Young in 1759. The imagination was fast drifting away from all reality of the earth, earthy.

"So boundless are the bold excursions of the human mind, that in the vast void beyond real existence, it can call forth shadowy being

[26] Fancy and imagination were used interchangeably in the early eighteenth century. Addison, *Spectator* No. 416, remarks, "I shall use them promiscuously."

[27] ". . . A clear head and acute understanding are not sufficient alone to make a poet; it is a creative and glowing imagination, *acer spiritus ac vis,* and that alone, that can stamp a writer with this exalted and very uncommon character . . ." Warton's *Essay* was dedicated to Young whose *Conjectures* were written in 1756.

and unknown worlds, as numerous, as bright, and perhaps as lasting, as the stars; such quite-original beauties we may call paradisaical."[28]

Dull reason was left to crawl abjectly upon the ground; imagination became a power to soar among the stars, to create what was "beyond real existence". If Young's literary dwelling-place was on a water-shed between the country of the neo-classic and that of the romantic, certainly in his conception of the imagination we have a stream of influence which flows down into the land of romance,—let us say of Shelley, or of Tieck and Novalis.[29]

IV

We now return to the paradox already mentioned, the paradox regarding the extreme popularity of the reactionary religious poet in a radical age. Sir Leslie Stephen points out Young's conservative trend: "The *Night Thoughts,* as he tells us, was intended to supply an omission in Pope's *Essay on Man.* Pope's deistical position excluded any reference to revealed religion, to posthumous rewards and penalties, and expressed an optimistic philosophy which ignored the corruption of human nature. Young represents a partial revolt against the domination of the Pope circle. He had always been an outsider, and his life at Oxford had, you may perhaps hope, preserved his orthodoxy."[30] Mr. H. C. Shelley regards Young, as the author of *The Centaur not Fabulous* (1754), as a comrade of both Wesley and Whiston "in fighting the common enemy of deism,"[31] as represented by the work of Bolingbroke. If there is no question that he was ostensibly reactionary, there can be no

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[28] *Conjectures on Original Composition,* (1759, London, 2nd edition), pp. 70–71.

[29] George Brandes (*The Romantic School in Germany,* London, 1902, p. 229) writes: "The task of literature in all ages is to give a condensed representation of the life of a people and an age. Romanticism contemptuously refused this task. Novalis in Germany and Shack Staffeldt in Denmark present the most typical examples of manner in which it turned its back on reality, to create a poetico-philosophic system out of the mind and the poetical longing of the author."

[30] *English Literature and Society in the Eighteenth Century,* London, 1904, p. 152.

[31] *Life and Letters of Edward Young,* London, 1914. P. 234.

question of his immense popularity. M. Thomas, at the end of his exhaustive study,[32] lists nearly forty editions in England alone before 1792 containing all or parts of *Night Thoughts*. Professor J. L. Kind's *Edward Young in Germany* contains a bibliography covering forty-five pages. Mr. Shelley says that *Night Thoughts* "was more frequently reprinted than probably any other book of the eighteenth century. It was to be translated into French, and Spanish, and Italian, and German, and Portuguese, and Swedish, and Magyar. . ."[33]

One may explain the popularity of this religious reactionary in a radical age in at least two ways. Either the age may have had a deep religious instinct, or his religion may have contained an alloy which the increasingly radical age found acceptable. The first alternative appears untenable when one considers the wholesale lack of spirituality in the pictures of the later eighteenth century found in Chesterfield's *Letters to his Son* (1773), or in Horace Walpole's letters. "There was a revolt," wrote J. R. Green, the historian, "against religion and against the churches in both the extremes of English society. In the higher circles of society 'everyone laughs,' said Montesquieu on his visit to England, 'if one talks of religion.' Of the prominent clergymen of the time the greater part were unbelievers in any form of Christianity, and distinguished for the grossness and immortality of their lives . . . At the other end of the social scale lay the masses of the poor. They were ignorant and brutal to a degree which it is hard to conceive." If we turn to the second alternative, have we any right to question the sincerity, or at least the quality of the aspiration, of Young's religion? Consider his life in London and his motives for entering the church. We recall that he did not take Holy Orders until the age of forty-four, after he was not—according to Croft—"an ornament to religion and morality." Mr. Shelley says of the prime of Young's life in London, "Nothing was more improbable at this time than that he should have become a minister of religion. His chief companions were the 'Wits' of the coffee-houses, the managers and

[32] *Le Poéte Edward Young*, Paris, 1901.
[33] *Op. cit.* p. 198.

players of Drury Lane, and ambitious politicians such as Wharton and Stanhope."[34] His pleasures were those of "the Thames and Vauxhall." Mr. Shelley, who defends Young at every step, is obliged to admit that Young's "chief reason for deciding to enter the clerical profession was a desire for . . . a settled income . . . ."[35] After assuming his sacred responsibilities, he is capable of courting royal favor through a most surprising letter to the King's mistress, Mrs. Howard, in which he parades his "Abilities," "Good Manners," "Service," "Age," "Want," "Suffering, and Zeal for his Majesty."[36] "There is as little of really deep sentiment as of sincerity," concludes Sir Leslie Stephen; "for, in fact, Young's hatred of the world revealed the disappointed patronage-hunter, rather than the religious enthusiast."[37]

Not to rely too much on biographical evidence, let us compare Young's aspiration with that of other Christian writers. St. Augustine testifies that man is restless until he finds his rest in God. The exiled, aspiring Dante finds that "In His will is our peace." Milton, suffering the misery of blindness alone in the fallen world of Restoration London, voices not despair but "timeless peace" in that last superb chorus of *Samson Agonistes:*

> "His servants He, with new acquist
> Of true experience from this great event,
> With peace and consolation hath dismissed,
> And calm of mind, all passion spent."

The mystic Vaughan aspires to "retreat" from a "heaven in sense" to "the way, which from this dead and dark abode leads up to God," a retreat which gave him peace and calm:

> "I saw Eternity the other night,
> Like a great ring of pure and endless light,
> All calm, as it was bright."

True Christian aspiration, one may conclude, is definite and focused: it is based on the imitation of Christ as he appears revealed in the Scriptures. Instead of exalting

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[34] *Op. cit.* P. 62.
[35] *Op. cit.* P. 93.
[36] *Op. cit.* P. 100.
[37] *English Thought in the Eighteenth Century,* London, Vol. II, p. 363.

desire, it progressively quenches it and leads to "the peace that passes understanding." Now let us examine Young's aspiration in contrast. Is his aspiration definite and focused, or is it indefinite and expansive?

"Extended views a narrow mind extend;
Push out its corrugate, expansive make,
Which, ere long, more planets shall embrace."[38]

"The soul of man was made to walk the skies;
Delightful outlet to her prison here!
There, disencumber'd from her chains, the ties
Of toys terrestial, she can rove at large;
There freely can respire, dilate, extend,
In full proportion let loose all her powers,
And undeluded, grasp at something great."[39]

We shall see later that Young is hostile toward the principle of imitation—"that meddling ape Imitation"—which gives direction and purpose to Christian aspiration. The next question is whether or not Young's aspiration leads to calm and peace, or to ennui and restless melancholy. He envisages "endless joys"—

"Joy breaks, shines, triumphs; 'tis eternal day.
Shall that which rises out of nought complain
Of few evils, paid with endless joys?[40]

But he has told us earlier of the reaction which is caused by his celestial reveries:

"Or is it feeble Nature calls me back,
And breaks my spirit into grief again?
Is it a Stygian vapour in my blood,
A cold, slow puddle creeping through my veins?
Or is it thus with all men?—Thus with all.
What are we? how unequal! now we soar,
And now we sink. To be the same, transcends
Our present prowess."[41]

Is there a relation between his inability to mediate between extremes and his dejection? We are reminded not so much of true Christian aspiration as of Shelley's plaintive question addressed to the benign "Spirit of Beauty":

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[38] *N. T., IX.*
[39] *Ibid.,* IX, 1018ff.
[40] *Ibid.,* IX, 2379ff.
[41] *Ibid.,* V, 216ff.

"Why dost thou pass away and leave our state,
This dim vast vale of tears, vacant and desolate?"

He asks

. . . "why man has such a scope
For love and hate, despondency and hope."

Thus, whereas true Christian aspiration is definite and focused, Young's is vague and expansive; whereas the Christian stresses the principle of imitation, Young rejects it; and whereas Christian aspiration generally leads to peace, Young's led to ennui and despair as we shall see more fully later.

Perhaps the precise quality of his aspiration will be somewhat more clearly perceived if we examine it in relation to the doctrines in the *Conjectures on Original Composition.* For, in many ways, the *Conjectures* is simply a prose amplification of doctrines set forth in *Night Thoughts.* In describing his heavenly flights Young exclaims,

"Far from my native element I roam,
In quest of New and Wonderful to man."[42]

In the *Conjectures* his yearning for novelty, expansion, infinitude finds expression through the glorification of an imagination emancipated from all purpose, restraint, and reality:

"In the fairy land of fancy genius may wander wild; there it has a creative power, and may reign arbitrarily over its own empire of chimeras. The wide field of nature also lies open before it, where it may range unconfined, make what discoveries it can, and sport with its infinite objects uncontrolled, painting them as wantonly as it will."[43]

Is this attitude very dissimilar from his so-called religious aspiration to "disencumber" his soul from toys terrestrial in order that she may "rove at large" and "grasp at something great"? The question now presents itself: Is not Young's religious aspiration akin to the later romantic nostalgia, the quest of Novalis for the Blue Flower, the quest of Shelley for "something afar from the sphere of our sorrow"? Dare we suggest that it is the presence of this

[42] *N. T.*, IX, 1758–59.
[43] *Conjectures*, p. 30.

indefinite, aimless, infinite expansiveness in the religious poetry of Young which accounts for his extreme popularity in an age of increasing radicalism?[44]

V

At any rate, Young's conception of the imagination helped advance the romantic "play-theory" of art. Plato and Aristotle had exalted the disciplined imagination as a means of penetrating into the heart of things, a means of visualizing the eternal realities of life. Dante had used the imagination to envisage the allotted destiny of humanity. It had enabled Milton "to justify the way of God to men." With the incursion of modern science, however, a different attitude developed: if to Aristotle poetry was the expression of the highest reality, to Lord Bacon it was an agreeable lie. And it is not without significance that Young should have chosen to derive his theories from the father of modern science,—"Bacon, under the shadow of whose great name I would shelter my present attempt in favor of Originals".[45] To Young art became a "consolation" for the *"tedium vitae"*. Instead of being the supreme work of the human mind, art became the most civilized form of play.[46] The aesthetic imagination was to "wander wild in its own empire of chimeras," to "range unconfined," to "sport with its infinite objects uncontrouled."

Young's conception of the imagination passed over to Germany and quickly merged into the nascent romanticism of that country. In his *Critique of Judgment* (1790),

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[44] The age is not without other examples of expansiveness masquerading as religion. Akenside remarks, for example, "The sovereign maker said . . . the soul should . . . enlarge her view/Till every bound should disappear." I find that the attitude suggested above has the partial support of as shrewd a student of religion as George Eliot; see her essay on "Worldliness and Otherworldliness: the Poet Young," p. 64, (in *Leaves in a Note-Book,* London, 1888) where she scores Young's so-called religious quest for "the remote, the vague and the unknown."

[45] *Conjectures* p. 69.

[46] It is true that Young once said that "Judgment . . . should bear the supreme sway; and a beautiful imagination, as its mistress, should be subdued to its dominion," but this was in the essay *On Lyric Poetry* (1728), thirty-one years before his final pronouncement in the *Conjectures.*

Kant[47] distinguished between two kinds of imagination: the scientific, sternly disciplined to reality; and the aesthetic, emancipated from all restraint whatever. And by freeing speculation from the subjective "forms" of time and place, he opened up limitless worlds for the conquest of the imagination. Schiller's novitiate in the school of Kant inspired him with the crusader's zeal to deliver art from the foils of the scientist; unwittingly, he betrayed the very citadel of art. In the *Letters upon the Aesthetic Education of Man* (1795), Schiller tried to solve the problem of shattered harmony by saying that only in play is man truly man; therefore art must be absolutely free and undisciplined to reality. Oscar Wilde is only a far-off echo of Schiller's *Gods of Greece* when he declares that the only beautiful things are those which do not concern us. Here we have the imagination straining away from a disagreeable reality towards something which never existed and never can exist,—the infinite, aimless longing of the romantic heart; as Pater was to say, "the Sangreal of an endless pilgrimage". I have said that certain of Young's doctrines feed those streams which ripple most gaily in the sunlight of romance; and it is the play *genre* of imagination which made possible the most charming of the phantasies of Novalis and the most exquisite of the fairy tales of Tieck. Nevertheless, it is a theory which gave presage of a decadent aestheticism, —of that poisonous heresy "art for art's sake", the divorce of art from life. The acme of this heresy is perhaps best seen in Schopenhauer, by whom, as Dr. Harald Höffding says, "the opposition between art and life posited by Kant and Schiller was ridden to death". "The value of art would ultimately disappear", Dr. Höffding reminds us, "if there were really no value in life.[48] And of this schism, by virtue of his disdain for life, his longing for death, his expansive imagination, and his view of "composition" as a "consolation" from the ennui of life, Young deserves the somewhat unenviable honor of being the partial source.

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[47] For a discussion of the similarities of the views of Young, Herder & Kant, see Kind, *Edward Young in Germany,* N. Y., 1906. p. 54.

[48] *History of Modern Philosophy,* London, 1920, Vol. II, p. 234. George Brandes, (*op. cit.,* p. 75ff) has a whole chapter entitled "Romantic Purposelessness."

VI

An imagination which sports with infinitude must almost necessarily chafe against restriction, and in Young's revolt against the rules we have an important corollary of his program of expansion. The school of Pope had deteriorated into the pseudo-classic emphasis on empty forms and rules; the thoughts and feelings of normal, healthy men which were not concurrent with these rules were bottled-up and denied expression in legitimate literature. Indeed, we may think of the whole romantic movement as of a great flood dammed up in the mountains, daily rising and chafing at its artificial barriers, until, with a mighty surge, it swept down walls and barricades and fences and rushed in turmoil to the sea. Thus Young not only marshalled his invective against imitation and rhyme—that "Gothic demon"—but also against the rules, which, "like crutches, are a needful aid to the lame, tho' an impediment to the strong."[49] To Voltaire Shakespeare had been a "drunken barbarian" chiefly because he ignored the rules; to Young he was an "adult genius", and *ne plus ultra,* because, among other things, he transcended the rules. Inasmuch as the domain of the rules was to be the battle-ground of the romanticists for some time, it is interesting to find Young among the first to challenge them. The most devasting attack upon the rules, curiously enough, was launched by that otherwise "eighteen-century" essayist, Macaulay.[50] And Keats used no equivocal terms when he cursed the age which had been wedded

> "To musty laws lined out with wretched rule
> And compass vile."[51]

VII

The love of infinitude almost inevitably leads to a distrust of the comprehensive powers of the intellect; limitless worlds are opened which transcend rational knowledge.

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[49] *Conjectures,* p. 28. Young's adoption of blank verse as opposed to the neo-classic heroic couplet exerted wide influence.

[50] In the essay on *The Doctrine of "Correctness."*

[51] *Sleep and Poetry.*

As a complement to Young's liberation of the imagination, it is quite appropriate that he should manifest a notable tendency, characteristic of the romantic movement generally, to disparage learning and logic in the interest of spontaneity and the teaching of nature. Burns, the peasant poet, exclaims,

"Gie me ae spark o' nature's fire!
That's a' the learning I desire."

And Blake was always hostile to any interference with the natural development of the individual genius. "There is no use in education," he told Crabb Robinson. "I hold it wrong. It is the great Sin." Rousseau's naturalistic educational program in *Emile* is of course well known. There is considerable controversy regarding Wordsworth's many slighting remarks about second-hand learning and the intellect—"that false secondary power by which we multiply distinctions"—but it seems reasonable to suppose that he, like Emerson, preferred to enjoy an "original relation to the universe." Of course this attitude was more or less of a revolt from the Cartesian and rationalistic endeavor to reduce everything to logical formulae. Kant, Hegel, Carlyle, Coleridge, and Emerson—not to mention lesser figures —exalted *Vernunft,* while they poured fine scorn upon the less inspired and more logical faculty, the *Verstand,* which John Locke placed at the head of his corner. And of this attitude it is interesting to find that Young was one of the earliest champions, half a century before the great romantic revolt came into full sway.

Inasmuch as his position has been stated in somewhat equivocal terms, there is need of making careful distinctions. Professor M. W. Steinke asserts that "his conception of God and man is not mystic, but rationalistic".[52] This assertion may be true so far as Young chooses reason as opposed to sense, since, as he believed, "one, in their eternal war, must bleed";[53] here once more, he is at the mercy of his fatal inability to mediate between extremes, to blend and harmonize the physical and the intellectual as

[52] *Edward Young's "Conjectures on Original Composition" in England and Germany* (N. Y. 1917), p. 13.
[53] *N. T.,* VIII, 856–62.

illustrated in the classical exaltation of *Mens sana in corpore sano.*

Young's reliance upon what he calls reason is not so much a recrudescence as a late survival of the "understanding age" of Addison and Pope. However, when we subject his ideas to careful discrimination, it becomes apparent that they represent a strange fusion—one might better say confusion—of somewhat incompatible views. In the first place, if we ask the motives for his choice of reason over sense, we find that he disowns sense not because of any Christian hatred of the flesh as the seducer of the spirit but because the sense can yield only "leaden iteration",[54] or in other words, because it can offer so little novelty of experience. Once more we have a hint of that ennui so common in later romanticism; witness Byron and Chateaubriand. The second motive for his homage to reason is even more enlightening: he scorns sense because, like all things terrestrial, it restricts and it confines; he exalts reason because

> "The Present is the scanty realm of Sense;
> The Future, Reason's empire unconfined."[55]

Now it is not altogether clear that there is anything very dissimilar between this "empire unconfined" which is supposed to be the domain of reason, and his imaginative "empire of chimeras" where "genius may wander wild" and "sport with its infinite objects uncontrouled". Young proposes reason as a means of restraint for the expansive desires; however, it is open to question whether reason, as he conceives it, is not itself expansive. Certainly these two, at least, of the motives which determine his choice of reason over sense are not usually thought of as influencing a true rationalist. It is clear, I think, that we need to be on our guard about the way Young uses the word reason, for his age has a mischievous way of using old words with new twists in their meanings.

Furthermore, if we examine the quality of his reason more in detail, we are not without a feeling of paradox; if he is a rationalist, it is but fair to add that he disdains all

[54] *N. T.*, III, 373–375.
[55] *Ibid.*, VII, 1432–34.

the means by which true rationality is usually acquired. "Genius needs not go to school."[56] "Many a genius, probably there has been, which could neither write nor read . . ."[57] And in the *Night Thoughts*, again,—although this particular passage has to do with religion—his respect for the heritage of the past is representative:

"Wouldst thou on metaphysic's pinions soar?
Or would thy patience amid logic's thorns?
Or travel history's enormous round?
Nature no such hard task enjoins: she gave
A make to man directive of his thought;
A make set upright, pointing to the stars,
As who should say, 'Read thy chief lesson there'."[58]

The reader wonders whether the "hard task" which learning would enjoin was not influential in suggesting a method so dear to that majestic indolence of Edward Young. Seldom has there been a more irrational eulogist of reason. The relation of his conception of reason to his nature cult is significant, and is a notable instance of a doctrine which was in great vogue in later romanticism. It would require no very dangerous stretch of the imagination to attribute the following sentiment to Wordsworth himself:

"Nature, Thy daughter, ever-changing birth
Of thee the great Immutable, to man
Speaks wisdom; is his oracle supreme;
And he who most consults her is most wise."[59]

Although there had been more or less controversy since the time of Jonson and Shakespeare regarding the relative merits of culture and native genius, the supporters of culture and the classics, such as Dryden, Swift and Pope, generally had the upper hand. Young's *Conjectures* was a powerful aid to the group who advocated reliance upon native genius. Young insisted that an original "rises spontaneously from the vital root of genius; it grows, it is not made."[60] Nature, originality, genius, and spontaneity be-

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[56] *N. T.*, VIII, 330.
[57] *Conjectures*, p. 36.
[58] *N. T.*, IX, 866ff. Notice the consonance between the views expressed in *Night Thoughts* and in the *Conjectures*.
[59] *N. T.*, VI, 671–74.
[60] *Conjectures*, p. 12.

came the great watchwords. The best art was supposed to be a sort of emanation of the folk,—those who lived closest to the sacred heart of nature. Even as early as 1735 Blackwell's *Homer* had explained the author of the *Odessey* as the result of a "concourse of natural causes." Allan Ramsay became a shining example of "original genius." Percy's *Reliques of Ancient Poetry* (1765) were collected to meet the growing demands for folk-songs; and the temptation to which Macpherson yielded had its roots in the same enthusiasm for the naive and the spontaneous. Somewhat later children came to be exalted as embodying these qualities, and we have Blake's *Songs of Innocence* and Wordsworth's famous glorification of a "six years' darling" as a "Mighty prophet! seer blest!" Later, of course, the love of the spontaneous became related to the primitivistic cult and the praise of a dim Arcadian past. Following Blackwell's interpretation of Homer, it is interesting to find Young among the first to proclaim the apotheosis of Shakespeare as an "original genius," a product of nature. "An adult genius comes out of nature's hand, as Pallas out of Jove's head, at full growth and mature: Shakespeare's genius was of this kind."[61] Schiller also exalted Homer as the supreme type of the naive poet: he "is nature."[62] Of the apotheosis of Shakespeare, however, Coleridge became the high priest, assisted by DeQuincey; the latter brings the attitude proclaimed by Young to a supreme climax: Shakespeare is "like the phenomena of nature," inerrant, inscrutable, transcendent.[63] Although Young may be, as Professor Steinke remarks, averse to "mystic" conceptions, it is evident that his conception of the "genius" tends to belittle the conscious adaptation of means to ends; the genius is like a magician.

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[61] *Conjectures*, p. 31.

[62] *Essay on Naive and Sentimental Poetry* (1795)

[63] See the conclusion of "On Knocking at the Gate in *Macbeth*": "O mighty poet! Thy works are not as those of other men, simply and merely great works of art, but are also like the phenomena of nature, like the sun and the sea, the stars and the flowers, like frost and snow, rain and dew, hail-storm and thunder, which are to be studied with entire submission of our own faculties, and in the perfect faith that in them there can be no too much or too little, nothing useless or inert, but that, the farther we press our discoveries, the more we shall see proofs of design and self-supporting arrangement where the careless eye had seen nothing but accident."

"For what, for the most part, mean we by genius, but the power of accomplishing great things without the means generally reputed necessary to the end? A genius differs from a good understanding, as a magician from a good architect; that raises his structure by means invisible; this by a skillful use of common tools. Hence genius has ever been supposed to partake of something divine."[64]

VIII

Although Edward Young cannot be credited with having inspired any detailed, minute, or picturesque description of nature, his attitude toward nature in general is worthy of examination. For his doctrine that the genius should rely upon nature is not altogether unconnected with another doctrine of signal importance, the doctrine that nature is a manifestation of the deity. In one of his nocturnal reveries, he exclaims:

> "This sacred shade, and solitude, what is it?
> 'Tis the felt presence of the deity."[65]

In a letter to the Duchess of Portland, 1742, he observes that "the whole creation preaches; I mean, that we can make no just observation on any of the appearances in the material world, but what will naturally have a good moral effect on us. The Sacred Scriptures, therefore, are very justly regarded as God Almighty's second volume, and creation as his first; which speaks to the same purpose, and if attended to, is ever bettering the human heart."[66] This, surely, is somewhat radical for the orthodox, who of course regarded supernatural revelation and the Scriptures as taking precedence over the volume Young ranks "first." But if Young was unwittingly tainted by the doctrine of Shaftesbury that nature is a manifestation of a benevolent deity, he armed himself resolutely against the Shaftesburian assumption that the natural man is instinctively good. He refers many times to "the depravity of our nature," and he once defines religion as "little more than curbing the natural

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[64] *Conjectures,* p. 26. John Foster accused the romanticists of a "violation of all the relations between ends and means." ("On the Epithet Romantic,") *Essays* (1805–06), Vol. I, (3rd edition).

[65] *N.T.,* V, 171ff.

[66] H. C. Shelley, *op. cit.,* quoted on p. 153.

tendencies of our perverse hearts."[67] Perhaps, like Pope, Young is a little muddled as to the ultimate implications of his various statements. The nature which is "ever bettering the human heart," although this nature needs "curbing,"

> . . . "is the Almighty's oath,
> In Reason's court, to silence Unbelief."[68]

Proof of a future life is found in the annual rebirth of nature:

> . . . "All, to re-flourish, fades;
> As in a wheel, all sinks, to re-ascend.
> Emblems of man, who passes, not expires."[69]

We have already noticed his theory that nature "speaks wisdom"; he remarks elsewhere,

> . . . "The stars call thee back;
> And, if obeyed, their counsel set thee right."[70]

It is scarcely necessary to mention the recognition of the divine life in nature in romantic literature. Wordsworth did homage to a god "whose dwelling is the light of setting suns," and Shelley proclaimed that "the universe is God" and "mixed awful talk" with his "great parent." Coleridge became a pantheist in *The Aeolian Harp* and *Frost at Midnight.* The rebellious Byron learned to "worship Nature with a thought profound," his altars being "the mountains and the ocean, earth, air, stars,—all that springs from the great Whole." Carlyle proclaimed that "The Universe is but one vast symbol of God," and his friend Emerson believed that man and nature were but parts of that "Unity, that Over-Soul, within which every man's particular being is contained and made one with all other."

Probably no word in the eighteenth century was used with a greater variety of meanings than the word "Nature." Pope, for example, had advocated that we "first follow Nature," but we learn that this is a nature "methodized," a nature "which is still the same," that "Nature and Homer were

[67] H. C. Shelley, *op. cit.*, p. 58.
[68] *N. T.*, IX, 845ff.
[69] *N. T.*, VI, 687.
[70] *N. T.*, IX, 641.

. . . the same." In place of a natural universality we find arising, along with the original genius theory, a natural diversity, a glorification of natural idiosyncrasy. Young opposes imitation because it forces us to "counteract nature," it "blots out nature's mark of separation."[71] This doctrine also differs, one should note, from Emerson's self-reliance which is, he tells us, reliance on "man's share of divinity," on the universal Over-Soul which makes all men brothers, the works of all mutually intelligible. The original genius was supposed to be unique, singular, and individual, especially as regards his knowledge. "Genius," Young says, "is from heaven, learning from man. Learning is borrowed, genius is knowledge innate, and quite our our own."[72] Not only is genius a purely individual matter, but nature itself, Young suggests, is partly a creation of the individual mind.

> "Objects are but th' occasion; ours th' exploit;
> Ours is the cloth, the pencil, and the paint,
> Which nature's admirable picture draws."[73]

This reminds us of Emerson's Fichtean dictum that "the Universe is the externalization of the soul," or—as Professor Myra Reynolds remarks—of Coleridge's *Dejection: An Ode*:

> O lady! we receive but what we give
> And in our life alone does nature live;
> Ours is her wedding garment; ours her shroud."

IX

Many critics like to think of classicism and romanticism as of alternate oscillations between collectivism and individualism, as an "antithesis between the individual's claims and society's, between synthetic law and individual liberty, between obedience to restrictions imposed from without and

[71] *Conjectures,* p. 42–43.

[72] *Conjectures,* p. 36. The history of the "original genius" cult has been brilliantly studied by Professor Paul Kaufman in "Heralds of Original Genius," an essay based on a Harvard doctoral dissertation, in *Essays in Memory of Barrett Wendell,* Cambridge, 1924.

[73] *N. T.,* VI, 431ff.

the spiritual demand for inner freedom."[74] Whether or not we accept this view as the whole truth, we cannot deny that it represents an important element in the romantic movement. And it is quite fitting that individualism should be remarkably salient in Young.[75] Inasmuch as Young's influence was felt most strongly in Germany, it may be not irrelevant to notice that Professor J. G. Robertson finds that the romanticism—the modernness—of Germany lies in

"the over-weening, even one-sided, individualism of German art; it deals more persistently and constantly with the individual human soul than with the external world; it is essentially subjective."[76]

It is to be expected from the rest of Young's philosophy that he should have gone to one extreme or the other—collectivism or individualism—and to be consistent with his other tenets he could not have chosen the former. As we shall see, his individualism has an astonishing number of ramifications, only the more important of which it will be possible to trace here.

In the first place the exaltation of the individual goes hand in hand with Young's refusal to imitate, for the imitation of a chosen model, whether literary or human, usually results not in differences but in likenesses. In accordance with the romantic edict "Follow Nature," there was the feeling that imitation tended to efface the natural individuality —one might almost say idiosyncrasy—which Young held to be the inalienable right of every man.

"By a spirit of Imitation we counteract nature, and thwart her design. She brings us into the world all Originals: No two faces, no two minds, are just alike; but all bear nature's evident mark of separation on them. Born Originals, how comes it to pass that we die copies? That meddling ape Imitation . . . blots out nature's mark of separation, cancels her kind intention, destroys all mental individuality . . ."[77]

In other words, by making war upon imitation Young hoped to nourish all those qualities which distinguished him from

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[74] J. G. Robertson, *The Literature of Germany* (Home University Library Edition). p. 142.

[75] In his attempt to account for the importance of Young's *Conjectures*, M. Thomas (*Op. Cit.* p. 484) concludes: "C'est surtout parce qu'il proclame les droits de l'individualité et qu'il insiste sur la notion du génie."

[76] *Op. Cit.*, p. 8.

[77] *Conjectures*, p. 42–43.

other men; he cherished his points of difference, his individuality. Earlier theorists, advocating the imitation of a definite standard of excellence, imaginatively conceived, had naturally stressed the development not of men's differences but their likenesses, their common humanity; this conception was common to both the humanistic and the Christian tradition. What, then, is Young's incentive in refusing to imitate? Very briefly, one may say it is his desire for superiority; for he firmly believed that to be different was to be superior. In the *Night Thoughts* he imagines himself as viewing the general race of men from some starry vantage-point, and it is clear that he takes pride in the knowledge that he is unlike his fellows in all things; as did the Pharisee, he thanks God that he is not as other men are.

> "Earth's genuine sons, the sceptered, and the slave,
> A mingled mob, a wandering herd, he sees,
> Bewilder'd in the vale; in all unlike!
> His full reverse in all! What higher praise?
> What stronger demonstration of the right?
> The present all their care, the future his."[78]

I am inclined to think that the following sentence from the *Conjectures* compresses much of Young's philosophy into a nutshell:

"All eminence, and distinction, lies out of the beaten road; and excursion, and deviation, are necessary to find it; and the more remote your path from the highway, the more reputable."[79]

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[78] *Night Thoughts,* VIII, 1089ff. Young's early insistence upon the merit of his uniqueness reminds one of Rousseau's famous words at the beginning of his *Confessions*: "Je ne suis fait comme aucun de ceux que j'ai vus; j'ose croire n'être fait comme aucun de ceux qui existent." Obviously, for this very reason—so far as it is true—Rousseau cannot serve as an example for others; universality, the "grandeur of generality," is lost. Professor Arthur Lovejoy (*PMLA,* Vol. XLII, p. 945) presents much scholarly evidence to support his thesis that "the general transition from universalism to what may be called diversitarianism" in the eighteenth century was promoted chiefly "by the emphasis and reiteration given to the principle of plentitude." "There has, in the entire history of thought," he concludes, "been hardly any change of standards of value more profound and more momentous." Coming from such a discriminating scholar, this fundamental distinction between neo-classicism and romanticism is of considerable interest; I would raise the question, however, whether what is called "diversitarianism" was not promoted as much by the "original genius" cult as by "the principle of plentitude."

[79] *Conjectures,* p. 23. It should be remembered that Young is simply the central figure in a whole group of writers who expressed ideas similar to his; witness Sharpe, Duff, Gerard, Colman, Wood, Hurd, Pikerton, Blake and others.

Superiority is thus directly proportional to eccentricity. And the motive for eccentricity—for deviation from the beaten road—is clearly the desire for eminence; his whole program of distinctiveness therefore radiates from egotism, and is contributory to egotism. Here we have the pivotal idea in his doctrine of original genius: a deliberate choice of extremes. This is the unifying centre—the nucleus—around which his philosophy may be related. It accounts, in part, at least, for his disdain of the world, "the beaten road"; for his love of solitude, "the remote"; for his love of "excursion" on the viewless wings of his imagination; and it is at the core of several more ideas with which I have yet to deal.

Accepting the desire for superiority as his determining incentive, Young sees life in terms of individual rivalry. Thus emulation becomes the key to his relations both with the ancients and with the moderns. This attitude was partly responsible for his hostility to the imitation of the ancients,—ancients and moderns should no longer be considered as "masters and pupils, but as hard-matched rivals for renown . . ."[80] "Imitation is inferiority confessed; emulation is superiority contested, or denied; imitation is servile, emulation generous; that fetters, this fires; that may give a name; this a name immortal."[81]

X

A man who is bent upon surpassing others is apt to concentrate all his energy upon one chosen endeavor. This is precisely what happened in the case of Young; it is entirely consistent with his philosophy that he should have glorified the master-passion, for obviously a man who centers all his efforts upon one subject has more chance of "distinguishing" himself therein than the man who seeks a rounded, symmetrical development. In the race for renown Young is anxious to lay aside every weight that besets him, and to focus all his attention on a single point.

"As for a general genius, there is no such thing in nature: A genius implies the rays of the mind concentr'd and determined to some par-

[80] *Conjectures*, p. 72.
[81] *Ibid.*, p. 66.

ticular point; when they are scattered widely they act freely, and strike not with sufficient force, to fire, or dissolve, the heart."[82]

In contrast, we think of the neo-classic Dr. Johnson's remarks on the master-passion: "This doctrine is in itself pernicious as well as false. . . True genius is a mind of large general powers accidentally determined to some particular direction." Johnson was of course simply voicing Aristotle's attitude toward specialization and natural bias, an attitude motivated by the desire not for progress but for individual happiness.

"We ought also," said the Stagirite, "to take into consideration our own natural bias, which varies in each man's case, and will be ascertained from the pleasure and pain arising in us. Furthermore, we should force ourselves off in a contrary direction, because we shall find ourselves in the mean after we have removed ourselves for from the wrong side, exactly as men do in straightening out a crooked stick."

Here we have the contrast between the theories rationalizing modern specialization and the theories of the advocates of the golden mean. It would be interesting to ponder upon the relation between present industrial unrest in our large cities and the warped, thwarted, and one-sided lives necessitated by the sub-division of labor of a machine civilization which exalts material progress above the sacredness of the individual human personality. And one of the factors behind this situation is certainly the glorification of the master-passion which evolved out of the theory of "humours" in the eighteenth century. While the Renaissance, with its classical heritage, had generally satirized the one-sidedness of "every man in his humour," near the end of the seventeenth century we find Congreve tending to defend "humours." A "humour," he writes Dennis, is "A singular and unaviodable Manner of doing or saying anything, peculiar and natural to one Man only; by which his Speech and Actions are distinguished from those of other Men." He further declares that "*Humour* is from Nature, *Habit* from Custom, and *Affectation* from Industry."[83] The relation

[82] *Conjectures*, p. 85.

[83] *The Select Works of Mr. John Dennis*, 1718, II, p. 514–525. The passage quoted appears in a letter dated July 10, 1695, entitled "Concerning Humour in Comedy."

between the "humour" and nature, and the slur upon Industry is significant. We cannot stop here to trace the gradual transition from the theory of humours to that of the ruling passion, but the relation is clear in Pope:

> " . . . One master-passion in the breast,
> Like Aaron's serpent, swallows up the rest . . .
> Each vital humor, which should feed the whole,
> Soon flows to this, in body and in soul . . .
> Nature its mother, habit is its nurse;
> Wit, spirit, faculties but make it worse;
> Reason itself but gives it edge and power."

It remained for Young to incorporate the theory of the master-passion into the myriad-sided theory of original genius.

The theory of the master-passion, however, does not derive entirely from the "humours." It is vastly significant that Young confesses himself a disciple of Francis Bacon, usually considered the father of our modern utilitarian movement.[84] Among the more important bequests of Bacon to which Young fell heir was the faith in the possibility of progress, or "perfectibility" as Godwin was to call it later. He is ever haunted by the analogy between progress in the world of science and the possibility of such progress in the world of art. "While arts mechanic are in perpetual progress and increase, the liberal are in retrogradation and decay."[85] And according to Young the source of this disparity lies in the prevalence of imitation; just as science questions all authority and refuses to imitate, so ought art to do. We were still intellectually moored to antiquity till Young cut the cable and gave us a chance at the dangers and glories of the blue water. His repudiation of authority in the literary field soon gave rise to repudiation of authority in general; and this break with the past and later with the traditional standards of goods and evil came simultaneously with the increased self-confidence which science inspired by its conquest over matter.

The belief in perfectibility—that faith in a mechanical and single-track advance of humanity—borrowed, as it is, from modern science, is of signal significance in romanti-

[84] "Two words," said Macaulay, "are the key to the Baconian doctrine—Utility and Progress."

[85] *Conjectures*, p. 41.

cism.[86] Indeed, Professor Barrett Wendell finds that the only trait common to all the unruly members of the romantic school was their agreement "in looking forward to an enfranchised future in which this world was to be far better than in the tyrant-ridden past. This was the dominant sentiment of English literature from the battle of the Nile to that of Waterloo."[87] And it is interesting that Young sounds the clarion of progress long before Godwin.

"Why should it seem altogether impossible that heaven's latest edition of the human mind may be the more correct and fair; that the day may come when the moderns may proudly look back on the comparative darkness of former ages, on the children of antiquity?"[88]

It is clear, also, that his faith in perfectibility tempted him to discard imitation. For imitation

"deprives the liberal and politer arts of an advantage which the mechanic enjoy. In these, men are ever endeavoring to go beyond their predecessors, in the former to follow them."[89]

In his zeal to "go beyond" his predecessors Young reminds us of the strange polarity which exists in the romantic movement: at one pole we have those who profess sympathy and brotherly love—Shaftesbury, Rousseau, Tolstoi; at the other the votaries of the "will to power"—Hobbes, Manderville, Napoleon, and Nietzsche.[90] Here, once more, we have the fatal weakness of the romanticists, the inability to mediate between extremes; they are unable to steer a middle course between Charybdis and Scylla, but must splinter their keel on one or the other. The question presents itself as to which of these extremes Young approaches. George Eliot, with few exceptions, finds in him "hardly a trace of human sympathy or of self-forgetfulness, in the joy or sorrow of a fellow-being."[91] On the other hand, his

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[86] For Bacon's belief in "progression" see *Advancement of Learning,* (Collected Works), Vol. I, p. 172.

[87] *A Literary History of America,* N. Y., 1900.

[88] *Conjectures,* p. 74.

[89] *Ibid.,* p. 41.

[90] Professor Kaufman (*op. cit.,* p. 216) concludes: "Further developed in more direct descent, the original genius becomes Carlyle's hero and culminates in Nietzsche's superman. Applied to the general human level, the faith in genius as one's essential self, and hence the complete reliance upon that self, is the pervasive teaching of Emerson and Whitman."

[91] *Op. Cit.,* p. 48.

guiding motive—the desire for superiority—may be more concretely described as the desire for fame; he even went so far as to call love of fame "The Universal Passion."

> "The love of praise howe'er concealed by art
> Reigns more or less, and glows in every heart."[92]

Manifestly, this is his principal incentive to literary composition. He conceives of the press as "the Fountain of Fame," and he objects to imitation because "An imitator shares his crown, if he has one, with the chosen object of his imitation; an original enjoys an undivided applause."[93] But what is the ultimate consequence of this passion for adulation? Toward which of the two poles does Young tend? His answer is unmistakable:

> "For a man not to grasp at all which is laudable within his reach, is a dishonor to human nature, and a disobedience to the divine."[94]

Thus Young's emulatory instincts, inflamed by his passion for "distinction," cause him to verge perilously near what we have come to associate with the "will to power." It is perhaps worth pondering whether there is not an element of similarity between Young's hortatory eulogy on grasping at all within one's reach, and—for example—Fichte's endeavours to arouse the martial spirit of the German people by his proclamation of the omnipotence of the expansive will: "What I will, I can; nothing is impossible."[95] One need only mention the philosophy of Napoleon, or Nietzsche, or even Bergson with his "élan vital." Of course the im-

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[92] *Satire* I, 52.

[93] *Conjectures*, p. 12.

[94] *Ibid.*, p. 77.

[95] *Reden an die deutsche Nation.* It should be recalled that Fichte was largely responsible for developing the idea of original genius on a national scale: nations are to cultivate those qualities which distinguish them from other nations—a theory which leads to an inbreeding of idiosyncrasies. The Germans were an *Urvolk*, the elect not of Calvin's God but of Rousseau's nature; the possession of character and German descent went together. "Charakter haben und deutsch sein ist ohne Zweifel gleichbedeutend . . ." (*Reden an die deutsche Nation, xii*). Herder says "An original writer, with few exceptions, is always a national author." (*Werke*, Vol. I, p. 402.) J. L. Kind, (*op. cit.*, p. 44) traced Herder's great "indebtedness to the *Conjectures*," and says he "did some of his best work in this direction, applying in a practical way to German literature the principles of Young, and thus passing beyond the arena of speculative thought into the arena of a noble patriotic cause."

plicit individualism in Young's conception of original genius which had been broadcast through France and Germany by his *Conjectures* was powerfully supported by Rousseau's doctrine of individualism and by his exaltation of instinct and emotion above reason. As regards Young, however, we look for some means of limitation, some curb, for this tendency to reach out expansively. What is to restrain his desire to be individual and superior? Inasmuch as he has ostracised imitation, there is lacking the centripedal force, the allegiance to a chosen standard, that might prevail against the powers of self-assertion. It is scarcely necessary to remark that here we stand at the headwaters of a current which was to sweep with devastating violence over the wartorn fields of France in 1917. Once more we catch a glimpse of the significance of this secluded spring high on the watershed between the country of Pope and the country of Rousseau.

XI

One implication of Young's individualism, often unnoticed, is the trend toward subjectivity,—a pronounced characteristic of later romanticism.[96] By subjectivity here, I do not mean so much the habit of introspection as the habit of seeing the outer world in terms of his own mind; everything, as we have seen, is painted on the walls of his own consciousness and is derived from within.

> "An inventive genius may safely stay at home. That, like the widow's curse, is divinely replenished from within, and affords us a miraculous delight."[97]

The view of the classicist, as expressed, for example, by Sir Joshua Reynolds, is in striking contrast:

> "The mind is but a barren soil; a soil which is soon exhausted and will produce no crop or only one, unless it is enriched with foreign matter."[98]

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[96] According to James Russell Lowell, the "subjective tendency" . . . "is one of the main distinctions between ancient and modern poetry." (*Function of a Poet*, Boston, 1920, p. 71.)

[97] *Conjectures*, p. 44–45.

[98] *Fifteen Discourses on Art.*

In Young's satisfaction with the confines of his own mind we have something that approaches the solipsism of later romanticism. All outer reality came to be stained and colored by the romanticist's own temperament; he came to see in nature only what he himself put there.

Of course, in the fresh morning of romance Young does not go to this extreme; but the subjectivity of his literary method, deriving from his all-embracing conception of original genius, is a straw in the current: "composition" opens "a backdoor out of the bustle of this busy and idle world, . . . the key of which is denied to the rest of mankind."[99] Thus the artist is distinctive and unique, and art becomes the utterance of his own uniqueness. Young's influence was here definitive: Doctor Johnson had insisted that art carry a universal import, that it express what is common to all men, the "grandeur of generality"; we can perhaps understand why the gruff old Londoner called but once on the clerical recluse when we find Young proclaiming that genius resides in one's idiosyncrasy, that ineffable something which makes him unlike any of his fellows. Art thus became uniquely subjective; the extreme romanticists could see outer reality only through the tiny windows of their own souls. And finally all that was left for them to universalize was their own inner selves,—their dreams and their emotions. "Eternity," declared Novalis, "is in us or nowhere." A method such as this led to constant introspection; and introspection may easily lead to self-pity and melancholy. It is probably of this phase of romanticism that Goethe was thinking when he made his famous dictum that the romantic is diseased, the classic healthy. In the famous first sentence of the *Characteristics*—"The Healthy know not their health, but only the sick."—Carlyle echoes Goethe in his judgment on the romantic subjectivity.

XII

Granting that we have now assayed the richest ore of Young's philosophy of life, the question arises as to its actual results. To leave this question unanswered would be

[99] *Conjectures*, p. 5.

to dodge the central current of his influence. For we must beware of the deceitfulness of abstractions, "the shadows of a shadow world"; of these the supreme maxim must ever be, "By their fruits ye shall know them." We have no guide to practical conduct here on earth save the oracles of experience which direct us by the flickering signals of joy and despair. If we admit that a man's fitness for the world in which he lives and his harmony with the laws of the universe are attested by a state not of melancholy but of happiness, we can find few more serious indictments against a view of life than that it ultimately leads to melancholy. Yet this is precisely what happens in the case of Edward Young; literary explorers have not been altogether wrong in supposing the secluded spring on the watershed dark and gloomy. However, his melancholy was not without precedent, and in order to understand it fully one should have a general idea of what had gone before.

In glancing at the melancholy which preceded Young, it is interesting to notice its close relation to solitude. Quite appropriately, Francis Petrarch, modern in his tastes, is noted for his melancholy, as one would expect who recalls his love of solitude, his egoism, his extreme desire for fame, and his hyper-sensibility. Along with other things Petrarchan, melancholy was imported by the English Renaissance. The descriptions by Roger Ascham and Ben Jonson indicate that it had become fashionable by the time of Elizabeth. Shakespeare's Jacques, an early and striking study of melancholy, is remarkable for his modern pretensions: his melancholy is different from that of anyone else,—it is his master-passion, his original genius; and he is proud of his excellent and affected differences.[100] Richard Burton, in his esoteric treatment of the subject, notes the relation of melancholy to solitude, and the fact that it is often cultivated for its atmosphere of distinction.[101] Representing, as he does, the confluence of the Petrarchan and Elizabethan streams, Burton is said to have suggested[102] to

[100] *As You Like It,* IV, 1ff.

[101] "Nullum solum infelici gratius solitudine, ubi nullus sit qui miseriam exprobet." (*Anatomy of Melancholy,* Pt. I, Sec. 2, Mem.. 2, Subs. 6.)

[102] By the prefatory stanzas to the *Anatomy of Melancholy.* These were written about 1601, or twenty years before the completed work.

Milton two poems of great influence in later romanticism—*L'Allegro* and *Il Penseroso*. The latter poem, filled with the spirit of Cambridge and sweet contemplation, represents melancholy as being induced by solitude.[103] After Milton for nearly a hundred years melancholy was evidently tabooed; the shadow of the grave and the mystery of the future were shunned by the rational Augustans. In 1721, however, Thomas Parnell[104] restored melancholy to literature, and, quite characteristically, a melancholy closely related to solitude; another element also appeared in Parnell which was significant for later romanticists,—namely the tendency to ruminate upon the futility of ambition and the certainty of death. Thus the Petrarchan and the Elizabethan type of melancholy merge into nascent romanticism in the early eighteenth century.

Young's *Night Thoughts* were published in 1742–45,[105] and, as we have seen, were greeted with immediate and unusual popularity; in this love of the lugubrious we have an index to the taste of an age which turned to questions of "Night, Death, and Immortality". Although continuing the literary conventions of the melancholy which had gone before and which was to become so distinct a note in later romanticism, Young gives us a still deeper undertone in the poetry of the graveyard than we find in the literature which preceded or followed; it was thoroughly characteristic of Young that he should have carried his melancholy to extremes. Considered in its historical relations, his type of melancholy represents a transition to the sentimentalism which resulted from the philosophy of Shaftesbury, of which Richardson's *Clarissa Harlowe* (1748),[106] Sterne's *Sentimental Journey* (1768), and Mackenzie's *Man of Feeling* (1771), are examples. In the last book Mr. Henry Morley find fifty outbursts of tears, and he did not stop to count the sobs. And with this peculiar dripping senti-

[103] The poem is made up of five solitary situations. Melancholy, in the invocation, is represented as the daughter of Solitude and Purity, or perhaps of Solitude and Genius.

[104] In *A Hymn to Contentment* and *A Night Piece on Death*.

[105] In regard to the date see *The Review of English Studies*, Vol. IV, p. 300 and pps. 414-417.

[106] A warm friendship existed between Richardson and Young, and the latter was loud in his praise of his friend's work.

mentality Young was by no means unsympathetic; in his eulogy upon that Christian paragon, Joseph Addison, he finds but one fault: too much of a "philosophic reserve"; "he should have let loose all his fire, and have show'd the most tender sensibilities of his heart".[107] In general, however, Young's complaint is not so much what we recognize today as sentimentality, as a sombre melancholy, or self-pity. Of course tumid Edward Young is not exactly the sort of man we should think of as indulging in endless jollifications; making allowance, however, for his constitutional aversion to unseemly merriment, it is readily apparent that he lacks that deep spiritual health which, for want of a better name, we call happiness. As Sir Leslie Stephen observes, "Indeed, if Young is not capable of a noble melancholy, he is in a thoroughly bilious condition."[108]

Inasmuch as external events frequently have a disagreeable way of altering the course of the finest philosophy, one ought to glance at Young's life before laying the undivided blame for his melancholy at the door of his romantic philosophy; his life was not without causes for unhappiness. A study of Young's biography leads to the conclusion that a natural predisposition to depression, the complement of his subjective and egotistical nature, was aggravated by sorrow and worldly disappointment. We are told that in those formative and fruitful years of college life he preferred to compose after midnight by the light of a candle stuck in a skull. It was just after college that Young's thoughts were turned toward death and

> "The grave, his subterranean road to bliss",[109]

by the death of William Harrison with whom he enjoyed a friendship not unlike that between West and Gray or that between Hallam and Tennyson. In *The Epistle to Lord Lansdowne,* (1713), Young laments for his friend, "the partner of his soul".[110] Notwithstanding repeated efforts to win fame and preferment, "in his thirty-fifth year,—his

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[107] *Conjectures,* p. 83.
[108] *English Thought in the Eighteenth Century,* London, Vol. II, p. 364.
[109] *N. T.,* VII, 10.
[110] Line 509.

prospects were no higher than in 1708".[111] Later, to be sure, with the publication of *Night Thoughts* he enjoyed no inconsiderable fame, but according to Sir Leslie Stephen he "never obtained the preferment to which he thought himself entitled", as we have seen. If we recall that his lode-star was fame, we can perhaps imagine how this reception affected him. To return to his early work, there is little of importance to be noted, save that as M. Thomas has pointed out, even in his youthful days he was "le poéte de la pensée melancholique".[112] Doubtless at first Young took delight in his melancholy; real sorrows are decidedly uncomfortable, but surely aesthetic ones are by no means unpleasant. Youthful melancholy is as normal as dentition; Young, however, seems to have been abnormally addicted to it, and as his sense gradually deadened he increased the dose until he ended in relatively genuine gloom. At first the debaucher, he became the victim of his sensations. In 1727 he abandoned the career of playwright, rewarded with meagre success, for the church; in 1730, at the age of forty-seven as we have seen, he was appointed Rector of Welwyn, where he retired, bitter at his failure to win the attention he thought he deserved, and henceforth almost as a theatrical troglodyte he "peeped at the world through the loopholes of retreat". Doubtless his priestly duties of comforting those who mourned, and his preoccupation with religious and moral treatises, tended to make his life more sombre. In 1741 his wife died, his step-daughter having died in 1736, and her husband in 1740. That he was not insensible to these events we may judge from the words of Mr. Shelley:

"Of all these losses, the one which affected him the most deeply was that of his wife; that was the culminating burden of his sorrows, having issue in sleepless nights and melancholy days."[113]

Furthermore, there can be little doubt that his depression was increased by his solitary habits and by the surround-

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[111] H. C. Shelley, *op. cit.*, p. 40.

[112] W. Thomas, *op. cit.*, p. 316. In *The Last Day* (1714) Young says his muse is a "Melancholy Maid" whom "dismal scenes delight."

[113] I have corrected here a regrettable error made in my paper entitled "A Study of Melancholy in Edward Young," (MLN, XXXIX Nos. 3 and 4)—of which the present study is an expansion—in citing from Mr. Shelley's valuable biography the date of Mrs. Young's death.

ings which he chose to remind him of the transitory character of human life; he displays a marvelous ability to extract the essence of melancholy from external objects. It is unnecessary to repeat the story of the alcove in his garden where he had a bench painted to give the illusion of reality, bearing the words "Invisibilia non decipiunt", or the fate of the sundial inscribed "Eheu fugaces!" His last years were lonely,—and melancholy.[114] "While his health permitted him to walk abroad, he preferred a solitary ramble in his churchyard to exercise with a companion on a more cheerful spot".[115] It was thus almost inevitable that pondering upon graveyards should lead to reflections upon the futility of ambition and universal mutability. His "first contribution to theology"—addressed to Queen Caroline—is supposed to be an argument against pessimism, but the reader can judge for himself as to its cheering tone; he has been considering all the passions of humanity as "contributing to human misery":

> "If this account is just, as I think it is, what is human happiness? A word, a notion, a day-dream, a wish, a sigh, a theme to be talked of, a mark to be shot at, but never hit, a picture in the head, and a pang in the heart of man! Wisdom recommends it gravely, learning talks of it pompously, our understanding listens to it eagerly, our affection pursues it warmly, and our experience despairs of it irretrievably."[116]

Nor is his final poem, *Resignation* (1762), much more exhilarating:

> "Of earth's revenue would you state
> A full account and fair?
> We hope; and hope; and hope; then cast
> The total up—*Despair*."

It is true, of course, that he expressed at times the hope of "endless joys" in the hereafter, but we have seen that the expansive element in his religion led to atrabilious reactions.

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[114] Sir Leslie Stephen, D. N. B., Vol. XXI, 1286, "Young's last years were melancholy."

[115] Rev. J. Mitford, "Life of Young," LVII, in *The Poetical Works of Young*, (Boston, 1854).

[116] Quoted by Shelley, *op. cit.*, p. 98, from "A Vindication of Providence" (1727).

However, in exposing possible sources of melancholy in the poet's life, as I have done, there is the danger of giving a distorted impression. To outward appearance his life was not as mournful as I may have suggested. Mr. Shelley very properly stresses the pleasanter side of Young's life, especially the fact that he entertained guests occasionally and could be witty in society. The truth of the matter is probably given in the words of his own son:

"He was too well-bred a man not to be cheerful in company, but he was gloomy when alone; he was never cheerful after my mother's death, and he had met with many disappointments."[117]

We have already seen that he preferred solitude,—not so much, perhaps, a physical as a psychic solitude due to a certain intellectual isolation and uniqueness. However, not to mention the good fortunes which were Young's, countless people—such as Milton, for example—have suffered far greater sorrows than his and have lost neither their cheerfulness nor their serenity of spirit. A more profound cause for his melancholy must be sought, therefore, and for that purpose we turn to his philosophy of life.

True happiness, it is probably safe to say, results chiefly from a mediation between extremes. The great problem of man is one of adjustment and compromise. At least this was the teaching of Aristotle and, in part, of Plato. This was the essence of the Horacian doctrine of the golden mean—*auream mediocritatem*—and Cicero's praise of *mediocritatem illam quae est inter nimium et parum.* Mr. G. K. Chesterton has recently advanced the thesis that Christianity is peculiar in reconciling opposites, in its balance. The classical and Christian traditions, at any rate, unite in stressing the doctrines of imitation, restraint, and a definitely focused aspiration. In the Middle Ages the "law for measure" was allied to the theory of the four humors, the balance of which meant health, the excess of any one of which accounted for a man's one-sidedness and meant disease. It is a commonplace, of course, that in the Renaissance—the rebirth of classicism—Ben Jonson satirized "Everyman in his Humor," and the tragic heroes of Marlowe and Shakespeare met their doom largely through

[117] Rev. J. Mitford, "Life of Young," lxi, in *The Poetical Works of Young*, (Boston, 1854).

some one weakness or one-sidedness. Hamlet, perhaps Shakespeare's greatest creation, knows that those who, "by the o'ergrowth of some complexion," carry

> . . . "the stamp of one defect, . . .
> Shall in the general censure take corruption
> From that particular fault."

And of Horatio, his soul's choice, he exclaims,

> . . . "blest are those
> Whose blood and judgment are so well commingl'd."

The Renaissance, however, gave birth to Bacon and modern science with its faith in progress and specialization; later the Royal Society lauded the virtuosi, men of surpassing acquisition in some one field.

Now balance and poise are generally the result of the disciplined and purposeful imitation of a balanced ideal envisaged by the imagination. Edward Young, by opposing imitation, by chartering of the imagination as a vehicle of idyllic escape, by translating the theory of humors—with the help of Bacon—into that of the master-passion, failed to mediate between extremes. Indeed, it is worth considering whether it was not precisely a failure of this sort which underlies most of his much-discussed melancholy;[118] for, if this study has served its purpose, it has indicated that his whole philosophy may be grouped around a choice of extremes as a nucleus. His scorn for the actual world and his devotion to the "vast Unseen"; his love of a distinctive solitude; his emancipation of the imagination; his expansiveness posing as religious aspiration; his rejection of the wisdom of the past and his preference for a unique original genius; his reliance upon the teaching of nature; his scorn for imitation and his insurgent individualism; his praise of the master-passion and the faith in progress; his singular subjectivity—all these have a common denominator: the choice of an extreme. I have endeavored elsewhere to demonstrate the relationship between Young's extremism and his melancholy.

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118 See Amy Louise Reed, *The Background of Gray's Elegy,* N. Y. 1924, p. 192ff. This is a scholarly study of the taste for melancholy poetry in the first half of the eighteenth century.

Perhaps the most important thing about Young's melancholy historically is its personal, subjective character. Classical and neo-classical melancholy had been in general objective and impersonal. Vergil's "majestic sadness," in Tennyson's phrase, resulted from the "doubtful doom of human kind." Gray brooded on the fact that "The paths of glory lead but to the grave." But Young, like Byron, is not averse to bearing the pageant of his own bleeding heart before the world.

"From short (as usual) and disturbed repose,
I wake: (how happy they, who wake no more!
Yet that were vain, if dreams infest the grave.
I wake, emerging from a sea of dreams
Tumultuous; where my wrecked desponding thought,
From wave to wave of fancied misery,
At random drove, her helm of reason lost.
Though now restored, 'tis only change of pain,
(A bitter change!) severer for severe.
The day too short for my distress; and night,
Even in the zenith of her dark domain,
Is sunshine to the colour of my fate."[119]

This introspective tendency has many sources. In addition to the expansiveness of Young's religion which casts a dark shadow on this world where, as Wordsworth said, "we find our happiness or not at all,"[120] his religion has a strong taint of egoism, as apparent in his summary:

"In self-applause is Virtue's golden prize."[121]
"Virtue is true self-interest pursued."[122]

We have already noted that his whole program of distinctiveness is motivated by the passion for "eminence." Another consequence of his theory of original genius is the impulse to introspection, to an escape into one's self. He loves night because

"It strikes thought inward; it drives back the soul
To settle on herself, our point supreme."[123]

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[119] *N. T., I,* 5ff.
[120] *Prelude,* XI. Oliver Elton (*A Survey of English Literature* 1780–1880, London, 1912, Vol. II, p. 95) finds Wordsworth practically the only romantic poet free from melancholy.
[121] *N. T.,* VII, 148.
[122] *N. T.,* VII, 143.
[123] *N. T.,* V, 129ff.

In the *Conjectures* "self-knowledge" and "self-reverence" are exalted as the supreme canons.

"Therefore dive deep into thy bosom; learn the extent, bias, and full fort of thy mind; contract full intimacy with the stranger within thee. . . . Thyself so reverence, as to prefer the native growth of thy own mind to the richest import from abroad."[124]

Of course genuine sorrow—and much of Young's was genuine—commands respect. Do we respect, however, a sorrow which becomes a mark of superiority? "His grief," he tells us, "is but his grandeur in disguise."[125] Thus the personal quality of his melancholy derives in part, at least, from his myriad-sided theory of original genius. For Young, believing that to be superior he must be unique, becomes unique in feeling, and therefore in suffering, evidently following the generalization made by Walpole that life is a comedy for those who think and a tragedy for those who feel. On one hand, the distinctive quality of his melancholy ministers to his egotism;[126] it distinguishes him from the "mingled mob" and therefore makes him superior. On the other hand, the uniqueness of his melancholy gives rise to what M. Thomas calls "un cri d' angoisse tout personnel. Ce qui manque à ces effusions pathétiques, ce n'est pas la sincérité mais l'universalité de l' émotion."[127] And there lies a deep significance in the fact that, after the somewhat artificial objectivity of the neoclassic age, the return of "I" to literature—the subjective, introspective, confessional note—should be inseparably linked with melancholy.[128]

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[124] *Conjectures,* p. 24.

[125] *N. T.,* V, 558ff.

[126] George Brandes (*op. cit., p.* 78) speaks of "the aesthetic stupor of self-contemplation and self-absorption which was the final development of Romanticism" in Germany.

[127] *Op. cit.,* p. 458. One exception is noted, *N. T.,* I, 238. It seems to me that there are more exceptions. In regard to the charge of hypocrisy in connection with Young's melancholy, M. Thomas says, "Cette supposition est non moins injurieuse que peu vraisemblable."

[128] J. L. Kind (*op. cit.,* p. 158) points out that "Herder discusses melancholy poets of the day, and places Young in the first rank." Goethe learned English from Milton and Young, and in *Aus Meinem Leben* (Bk. XIII) he "characterizes the effect that the gloomy English poets had upon Germany at that time, and attributes to them, mentioning the *Night Thoughts* as the work in which the pessimistic weariness of life is preeminently worked out, the conditions that caused *Werther* to strike a responsive chord elsewhere."

Of course Young's melancholy is but a foreshadowing of the pervasive melancholy which one finds everywhere in the romantic movement. Although "felicity is the great fact of Wordsworth's life,"[129] even this serenest of the romanticists felt his anchor drag at times, as Ruskin noted: "Great God," the poet exclaims,

"I'd rather be
A Pagan suckled in a creed outworn;
So might I, standing on this pleasant lea,
Have glimpses that would make me less forlorn."

Everyone remembers Coleridge's painful confession, in *Dejection: An Ode,* of

"A grief without a pang, void, dark, and drear,
A stifled, drowsy, unimpassioned grief,
Which finds no natural outlet, no relief,
In word, or sigh, or tear."

John Keats forever lamented the transient loveliness of a sensuous world

. . . "where men sit and hear each other groan;
Where palsy shakes a few, sad, last gray hairs,
Where youth grows pale, and spectre-thin, and dies;
Where but to think is to be full of sorrow
And leaden-eyed despairs."

"I fall upon the thorns of life! I bleed!" Shelley confides. In the *Stanzas Written in Dejection* his despair is laid bare:

"Alas! I have nor hope nor health,
Nor peace within nor calm around,
Nor that content surpassing wealth
The sage in meditation found,
And walked with inward glory crowned—
Nor fame, nor power, nor love nor leisure.

"Yet now despair itself is mild,
Even as the winds and waters are;
I could lie down like a tired child,
And weep away the life of care. . . . "

(Kind, *op. cit.,* p. 109) In France, according to E. Baldensperger, ("Young et ses 'Nuits' en France," in *Études d'Histoire littéraire*) Young was one of the major influences behind the vogue of melancholy literature.

[129] F. W. H. Meyers, *Wordsworth,* London, 1925, p. 72.

Lord Byron tells us that, "grown aged in this world of woe," he writes *Childe Harold* to "fling forgetfulness around me,"[130] and the Byronic egotist Manfred—with all things offered him—prays only for "Self-oblivion." And at the end, in *Don Juan,* he confesses with infinite sadness,

> "And if I laugh at any mortal thing,
> 'Tis that I may not weep; and if I weep,
> 'Tis that our nature cannot always bring
> Itself to apathy."

We may safely conclude, then, that the shadows which stole upon the author of *Night Thoughts* were but early adumbrations of those which were to fall upon later romanticists.[131]

SUMMARY

We have discussed the following major traits appearing in Young's work:

(1) scorn for the commonplace and the actual world;
(2) praise of a solitude unique and distinctive;
(3) apotheosis of the lawless, creative, idyllic imagination;
(4) indeterminate expansiveness in the guise of religious aspiration;
(5) praise of art as a means of play and of escape;
(6) contempt for rules and restrictions;
(7) preference for native genius rather than culture and the classics.
(8) recognition of nature as "the felt presence of the deity;"

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[130] Young (N. T., I, 45) tells us, somewhat as Byron does, that his is "A mind that fain would wander from its woe."

[131] A host of thinkers and scholars testifies to the pervasive melancholy of the romantic movement and the nineteenth century. See, for example, the following: J. R. Lowell, *Prose Works,* Boston, 1894, Vol. III, p. 94; John Ruskin, *Selections and Essays by Ruskin,* edited by F. W. Roe, N. Y., 1918, p. 134; Walt Whitman, quoted by N. Foerster, *American Criticism,* Boston, 1928, p. 191; Thomas Hardy, *Tess of the D'Ubervilles,* N. Y. 1921, p. 132; Arnold, *Passim;* Walter Pater, *Appreciations,* London, 1889, p. 105; Bourget, *Essais de Psychologie contemporaine,* in the essay on Flaubert; H. A. Beers, *A History of English Romanticism in the Eighteenth Century,* N. Y., 1916, p. 115 (Victor Hugo is here said to have called melancholy the distinguishing badge of romantic art); Irving Babbitt, *Rousseau and Romanticism,* Boston, 1917, p. 307; Oliver Elton, *Op. cit.,* Vol. II, p. 95.

(9) hostility to imitation and praise of militant individualism;
(10) glorification of the master-passion and the hope of progress;
(11) praise of a unique and idiosyncratic subjectivity;
(12) the parading of a personal and singular melancholy.

While one may concede that these traits are not always the *major* traits of the greater romanticists, I have tried to show that all of these traits are manifested in one way or another in the literature which by common consent we call romantic.

NOTE:—In accordance with the terms of the award, statement is here made of the fact that this study—in slightly different form—was awarded the Bowdoin Prize in English in the Graduate School of Harvard University for the year 1924. I wish to record my appreciation of the kind suggestions of Professors Irving Babbitt and John L. Lowes, under whose direction the study was originally begun, as well as those of Professor Henry B. Lathrop of the University of Wisconsin. H. H. C.

The University of Wisconsin
January 10, 1929.

WISCONSIN INDIANS DURING THE AMERICAN REVOLUTION

LOUISE PHELPS KELLOGG

When the Revolution began, Wisconsin had been for only fourteen years under British sovereignty and the Indians were not entirely reconciled to the officials sent to preserve order in this distant part of the British Empire. They had been restless from the moment a British force had advanced from Mackinac and had taken possession of the old French post at Green Bay. The Maryland officer who was sent to pacify these more than thirty thousand savages, dependent upon his post, was appalled at his task. However, he succeeded better than most of his contemporaries, since when Pontiac's Conspiracy broke out in 1763 the little post he had grandiloquently named Fort Edward Augustus was the only one in the West not attacked by hostile tribesmen and its commandant was called upon to come with his Indian allies to the aid of the captured officers and garrison at Mackinac.[1] So faithful were Wisconsin Indians to British interests that at the great conference called at Niagara in 1764 by Sir William Johnson to settle differences the "Old King" of the Menominee Indians was paid signal honors by Johnson himself.[2] Although Fort Edward Augustus was never regarrisoned, Wisconsin Indians were for the next decade, on the whole, obedient to British orders. When Robert Rogers at Mackinac in 1766–67 sent his subordinates, Captains James Tute and Jonathan Carver to pacify the Wisconsin Indians they induced the Sauk and Foxes as well as the Sioux to abandon the French and Spanish traders, who were coming up the Mississippi from St. Louis, and go to Mackinac to renew their allegiance with the English king.[3] Rogers gave them large presents to bind their troth, so large that he was rebuked by his superiors for his extravagance. Thus at the

[1] *Wis. Hist. Colls.* I, 24–48.
[2] *Wis. Hist. Colls.* XVIII, 268.
[3] *Wis. Magazine of History,* XII, 139–140.

beginning of the Revolutionary years, the British were in control of the Indian situation. The trade centered at Mackinac and passed through the Fox-Wisconsin route to the Mississippi. Adventurous French Canadians had even attempted to obtain the Spanish trade on the Missouri, but were caught and punished by the watchful authorities at St. Louis. Farther north along the Des Moines and the St. Peters the British carried the fur trade into Spanish Louisiana with impunity.

One reason the Wisconsin Indians were so well controlled by the British authorities was because the French residents of Wisconsin had taken an oath to the British sovereign and their leaders had become officials of the Indian Department. Charles de Langlade, a captain in the British service, resided at Green Bay and kept the eastern part of the present state in order, while his nephew Charles Gautier lived at Prairie du Chien and was influential with the Mississippi tribesmen. When the American rebels threatened Canada Sir Guy Carleton sent word to Langlade to come to his assistance and during the early years of the Revolution, Langlade led annually a contingent of Wisconsin Indians to oppose Montgomery, Arnold, and the American officers who were trying to add Canada as the fourteenth state to the new American nation.[4]

Meanwhile, forces were gathering in the West which were to make the British hold over Wisconsin Indians precarious. Early in 1778 a young colonel from Virginia planned to protect the outlying settlements of that state by carrying the offensive into the enemy territory. The fourth of July of that year George Rogers Clark captured the British post of Kaskaskia and within a few days had taken Cahokia and all the outlying settlements for the Americans. Clark also made friends with the Spanish commandant across the river and thus controlled all the middle region of the Mississippi. We speak of Kaskaskia as a British post, and so it was technically; its residents, however, were all of French descent and when Clark informed them that the French king had made an alliance with the American

[4] *Wis. Hist. Colls.* XVIII, 355–358.

rebels, they all cheerfully took the oath of allegiance to the new nation.

By this action the Wisconsin Indians were thrown into a turmoil. Clark's French agents at once found their way to the villages on Rock River and carried American peace belts as far as Prairie du Chien and the portage. Overjoyed at the prospect of the return of their old French "fathers," the Wisconsin chiefs hastened to the Illinois to meet the conqueror. At Cahokia in August and September, 1778 an immense concourse of northern Indians gathered and held council with George Rogers Clark. Langlade was in Canada with a large force of Wisconsin tribesmen supporting Carleton; no one in Wisconsin was able to restrain the curiosity of the Indians left at home to see the "Big Knife" American. This was not an individual name for Clark, but was the Indian name for first, the governor of Virginia; second, all Virginians; third, all Americans.

Clark's account of the series of treaties he negotiated with the Northwestern Indians at Cahokia on the Mississippi is interesting in the extreme.[5] He states that there were present Chippewa, Ottawa, Potawatomi, Mississaga, Winnebago, Sauk, Fox, and Iowa Indians, who conducted the ceremonies with the dignity and solemnity befitting the occasion. "I suppose," he wrote, these negotiations had "as much Dignity and Importance in their eyes as the treaty between France and America in ours." Clark developed a new technique in dealing with the natives; he assured them that he was absolutely indifferent whether they accepted peace with the Americans or not. "I carry in my right hand war and in my left peace," he told them, and explained that the Great Council fire at Philadelphia had sent him to clear the roads for those who wished to be friends with the Americans. They might choose which they pleased, peace or war, but if the latter, then their women and children would be subjected to grave danger.

The chiefs greatly admired the courage and indifference of the "Big Knife"; they hastened to assure him of their sympathy and that they would repudiate the British alliance for one with him. Clark gravely responded to their wishes,

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[5] *Ill. Hist. Colls.* VIII, 125–129, 243–248.

and drew up treaties and certificates, clinching their new allegiance. Two of these certificates have been preserved; that with the Winnebago chief of Rock River, and one of those given to the head Fox chief.[6]

A separate account of Clark's dealings with the Milwaukee Indians appears in his writings. The Indian village at that place was of mixed composition—Ottawa, Chippewa, and Potowatomi; their chief Blackbird or Letourneau whose Indian name was Siggenauk, was an Ottawa who had married a Potawatomi and had identified himself with the latter tribe.[7] Clark, however, called him a Chippewa. Somewhere Siggenauk had acquired the manners of civilization and when visiting Clark, at the latter's invitation, "attempted to speak as much in the European manner as possible."[8] Clark humored him and made fast friends with him and so successful was he in attaching this chief and his band to the American interest, that the British officer at Mackinac spoke of them as "those runagates at Milwakie", and sent Gautier by ship to arrest him. Blackbird, however, had flown and although a reward was offered for him if fetched in either by fair or forced methods, he was not captured and remained true to the "Big Knife" during all the years of the Revolution.[9]

It would be tedious to relate in detail the duel that ensued during the latter years of the Revolution between Clark and Langlade for the alliance of the Wisconsin Indians. After Clark's capture of the British Governor Hamilton at Vincennes, his fame soared aloft among all the western tribes, who fell away from the British to such a degree that Mackinac trembled for its safety. It was at this time that the garrison was removed from the south shore, and the fort built on the island so as to be more secure from capture by the enemy. The commandant reported that only the Sioux Indians were faithful to the British.[10] The next year, 1780, the British expedition against St. Louis was

[6] *Wis. Hist. Colls.* XI, 113, 177.

[7] Description of this chief and his son, the author of the Chicago massacre of 1812, is in the *Miners' Journal,* Galena, Ill., Oct. 30, 1830.

[8] *Ill. Hist. Colls.* VIII, 253–257.

[9] *Wis. Hist. Colls.* XI, 201; XVIII, 384.

[10] *Wis. Hist. Colls.* XI, 144.

joined by a considerable Indian contingent, which deserted its leaders on the rumor that Clark was at Cahokia preparing to cross the river to aid the Spaniards in their defense. Indeed, it was reported to British headquarters that the expedition failed because of the treachery of the Sauk and Foxes.[11] The Winnebago, on the other hand, had a chief and three men killed and four wounded, the only Indians who suffered in the British cause.[12]

So the alliance wavered, now on one side, now on the other, with the fortunes of the contestants. The close of the Revolution, however, found the British largely in control, due to their ability to bribe the tribesmen with presents. The American Congress was too poor to send a large amount of goods and ammunition to their Indian allies; while the British, with greater means and in control of the Great Lakes, were able to forward to Detroit and Mackinac large invoices of Indian presents. The Wisconsin Indians should not be considered wholly mercenary, selling their friendship to the highest bidder. White men's goods were necessary to their very existence: without powder and lead for their guns they could not hunt; without blankets and cloth they would be exposed to the elements, mayhap freeze to death; without game and furs which they had to trap or shoot with white men's implements, they had no means of livelihood. It should be remembered, however, especially in this year of the George Rogers Clark Sesquicentennial, that had not the Wisconsin and other Western Indians made a temporary alliance with Clark at Cahokia in 1778, he could not have maintained his position in Illinois, nor conquered Vincennes, nor protected Kentucky. And had it not been for Clark and his conquests, might not this great Northwest, now so important a part of the United States, have remained, as it then was, a part of Canada and become a portion of the British Empire? These suggestions may explain the importance of the rôle played by the Wisconsin Indians in the American Revolution.

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[11] *Wis. Hist. Colls.* XI, 147–157; XVIII, 404–408.
[12] *Wis. Hist. Colls.* XI, 156.

THE SETTLEMENT AND THE DISTRIBUTION OF THE POPULATION IN WISCONSIN*

GUY–HAROLD SMITH

HISTORICAL INTRODUCTION

The westward movement of settlers from the Atlantic seaboard into the virgin lands beyond the Appalachians is epochal in American history. The pioneers of early American stock were joined by the foreign immigrants and together they pushed westward into the new lands. After 1763 there began a steady stream of frontiersmen who cut away the forests and established permanent settlements as soon as, and even before, the land was acquired from the aborigines. Everywhere they were confronted with differing physical conditions to which they consciously or unconsciously adapted their activities.

About 1820 the frontier of settlement reached that portion of the Old Northwest that was later to be circumscribed by the boundaries of the State of Wisconsin. The new lands of the future state presented to the settlers a variety of habitats each differing more or less from the others. These differences in regional geography have produced a population sectionalism that has persisted for a hundred years.

Preliminary Exploration. The geographical conditions of the State of Wisconsin, since the visits of the first white men, have invited and guided exploration, immigration and settlement. No doubt, the unwritten history of the aborigines is filled with episode and incident reflecting the influences of forests, prairies, lakes, and streams upon the trails followed for game or for enemies, upon the selection and division of hunting grounds, and the reservation of ceremonial and burial sites.

Not only did the geographical conditions within the state

* A brief regional summary article on this subject entitled "The Populating of Wisconsin" was published in the Geographical Review, Vol. XVIII, No. 3, July, 1928, pp. 402–421.

influence the course of history, but the orientation of lakes and streams beyond the present boundaries guided and directed explorers toward Wisconsin. Schafer writes that,

> . . . The imposing geographic arch formed by the Mississippi lands on the one hand and those of the Great Lakes and the St. Lawrence basin on the other has for its keystone the territory embraced within the boundaries of Wisconsin. Resting lightly on Lake Superior but with a long shore line on both Lake Michigan and the Father of Waters, that territory also holds the most convenient line of communication between the two systems, the Fox and Wisconsin Rivers, separated by a single short portage. This explains why so much of the early history of the State not only connects but mingles and blends with the French history of Canada and Louisiana . . .[1]

Miss Kellogg, in one of a series of articles on the early history of Wisconsin, has called attention to the importance of geography in the discovery and exploration of the region. She notes that,

> . . . Wisconsin's position at the headwaters of the two great valleys of North America—the St. Lawrence and the Mississippi—has been of supreme importance in the history of the State. To these advantages of position is due its early discovery, its thorough exploration, and its value as a link in the penetration of inland America.[2]

Turner, the foremost student of American frontier history, has made the following observation in his studies of the fur trade.

> . . . The importance of physical conditions is nowhere more manifest than in the exploration of the Northwest, and we cannot properly appreciate Wisconsin's relation to the history of the time without first considering her situation as regards the lake and river systems of North America.[3]

The French Régime, 1634–1763. The first white man to set foot upon the territory, which was later to be included within the boundaries erected to delimit the Territory, and still later the State of Wisconsin, was Jean Nicholet. His

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[1] Joseph Schafer. A History of Agriculture in Wisconsin. (Wisconsin Domesday Book, General Studies, Vol. 1), Madison, 1922, p. 1.

[2] Louise Phelps Kellog. The Story of Wisconsin, 1634–1848. The Wisconsin Magazine of History, Vol. II, March 1919, p. 257.

[3] Frederick J. Turner. The Character and Influence of the Indian Trade in Wisconsin. Johns Hopkins University Studies, Vol. IX, 1891, p. 559.

journey under the direction of the indefatigable Champlain illustrates not only that the latter ". . . wished to test his theory that the route to the East lay through the Great Lakes,"[4] but how the lakes and tributaries from the beginning directed the course of exploration toward Wisconsin.

Nicholet ascended the Ottawa River and crossed by way of Lake Nipissing into Georgian Bay which gave him easy access by way of the Straits of Mackinac to Lake Michigan and its important arm, Green Bay, near the head of which he landed in 1634. (Fig. 1).

> . . . We are now able to see how the river-courses of the Northwest permitted a complete exploration of the country, and that in these courses Wisconsin held a commanding situation. But these rivers not only permitted exploration: they also furnished a motive to exploration by the fact that their valleys teemed with fur-bearing animals . . . The hope of a route to China was always influential, as was also the search for mines . . .[5]

There were manifold motives that directed the pioneer explorers into Wisconsin. To some the impelling motive was a search for a passage across the North American continent to the Pacific Ocean, and the discovery and exploration of the Great Lakes stimulated this vain hope. To others exploration was secondary to the diplomatic services they might render in securing the friendliness of the Indians with whom the fur trade was to become the economic basis of an important commerce. Still others hoped to find mines and duplicate the wealth Spain was reputed to have won from the Indians of Mexico and South America. Whatever motive was dominant the orientation of the lines of communication brought Wisconsin in touch with the settlements along the lower St. Lawrence River at an early date.

After Nicholet's visit of 1634 exploration progressed rather slowly because of the hostility of the Iroquois Indians, but the explorers, missionaries, and traders gradually worked westward from lower Canada into the Upper lakes country. Among the missionaries were the explorer Louis Joliet and Father Jacques Marquette who in 1672

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[4] Louise Phelps Kellogg. The French Régime in Wisconsin and the Northwest, p. 78.

[5] Turner. Ibid. p. 562.

ascended the Fox River, portaged to the Wisconsin and descended it to its junction with the Mississippi.

Up to the end of the French and Indian War in 1763 Wisconsin's bordering lakes and penetrating streams guided

FIG. 1. This identification map gives the names of the modern counties of Wisconsin and the location of twenty important cities.

the hardy pioneers into the heart of the area. The many straits, portages, river mouths and important lakes became the strategic sites of the fur trading posts, and Green Bay became the commercial capital of Wisconsin.

The traffic in furs was of such importance that the profitable returns stimulated the traders to penetrate farther into the interior of the country, and while very few of these French, and French and Indian half-breeds became permanent settlers there must have been a few hundred of them who spent a major portion of their lives in Wisconsin. They came, principally, from Quebec with their many iron implements and interesting trinkets, guns, and 'fire water' with which they bargained for the furs. This systematic trade with the Indians put into their hands a new weapon and stimulated the Indian to hunt the fur-bearing animals beyond their own requirements. "They passed also from the economic stage in which their hunting was for food and clothing simply, to that stage in which their hunting was made systematic and stimulated by the European demand for furs."[6]

The traffic in furs led to an exploitation which was in some ways detrimental to the Indians, but the traders rendered a valuable diplomatic service in preparing a way for the people who were to come later. They became the liaison agents between the Indians and the miners and farmers who were soon to follow. Also they constituted the vanguard of the sedentary population.

The British Sovereignty, 1763–1816. The fall of Quebec in 1760 virtually ended the French sovereignty in Wisconsin, but the change to the British control altered only slightly the fur trade so far inland as Wisconsin. The British began to displace the French in some of the important posts and significant changes were made in the organization of the industry. With the coming of the British—particularly the Scotch, ". . . there began that long and brilliant dynasty of Scotch fur barons which has endured down to our own day."[7] The French-Canadians were not displaced but merely utilized to carry out the details of the traffic directed and financed by the British who established posts and invited the Indians to bring in their furs. Under this plan another step toward the permanent occupation of the land had been taken.

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[6] Ibid., pp. 31–32.

[7] Clarence W. Alvord. The Mississippi Valley in British Politics, I. p. 296.

American Control after 1816. The Treaty of Paris in 1783, which marked the close of the Revolutionary War and transferred Wisconsin from the British to the Americans, was only a 'scrap of paper ' so far as any change in the fur trade was concerned. The traffic was maintained after the war as before with little or no opposition except from a few American traders. And concomitant with the commercial activities there was maintained a virtual political sovereignty of territory no longer British. John Jay was sent to London to make a commercial treaty with the British involving among other things a settlement of the northwest boundary troubles. He received a promise to withdraw in 1796, at which time Wayne's army took over the post at Detroit. From that date to the War of 1812 America extended her sovereignty over Wisconsin, only to relinquish it at the outbreak of hostilities when the British ". . . with Indian assistance, seized the American posts up to a line indicated by Toledo Bay, Fort Wayne, Peoria and St. Louis."[8] After the war American sovereignty was again established and Federal troops were sent to Green Bay and Prairie du Chien in 1816, when control by the United States became effective for the first time.

The geographical remoteness of Wisconsin is an important circumstance explaining this vacillation in political sovereignty and the delay in settlement of an area so long known to white man. But after American dominance was established this section of the Old Northwest began to attract settlers.

The First Settlements. By 1820 the white population had begun to localize in one or two places, making possible an estimate of the actual number of permanent settlers. Green Bay and Prairie du Chien were the only important settlements in Wisconsin at this time. "The former, chiefly limited to the stretch of five miles up the Fox River from its mouth, consisted of about sixty houses, with a population of perhaps 500 souls, besides which was a garrison."[9] Many of these people were settlers who utilized the land and

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[8] Frederic L. Paxson. History of the American Frontier, 1763–1893, p. 179.

[9] Frederick J. Turner. The Character and Influence of the Fur Trade in Wisconsin, Wisconsin Historical Proceedings, 1889, p. 92.


POPULATION MAP
of
WISCONSIN
1850
Scale
Guy-Harold Smith
LEGEND
CITIES AND VILLAGES
200 ~ 1000
1000 ~ 2500
5000
10,000
25,000
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Each dot (•) represents 25 rural people localized by civil townships. The location of approximately 8000 Indians in northern Wisconsin is not shown on the map.
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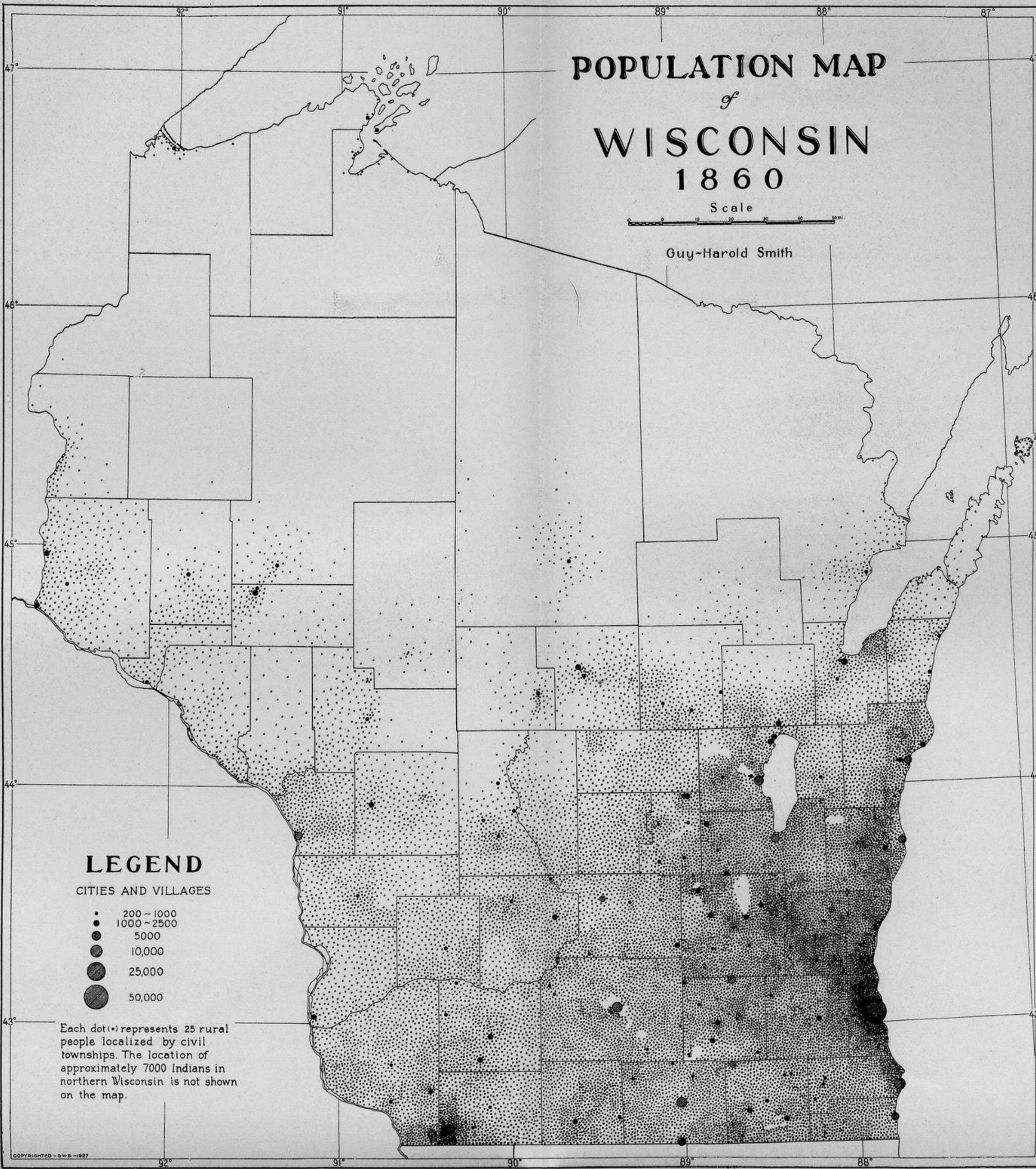

POPULATION MAP
of
WISCONSIN
1860
Scale
Guy-Harold Smith
LEGEND
CITIES AND VILLAGES
200 ~ 1000
1000 ~ 2500
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Each dot (•) represents 25 rural people localized by civil townships. The location of approximately 7000 Indians in northern Wisconsin is not shown on the map.
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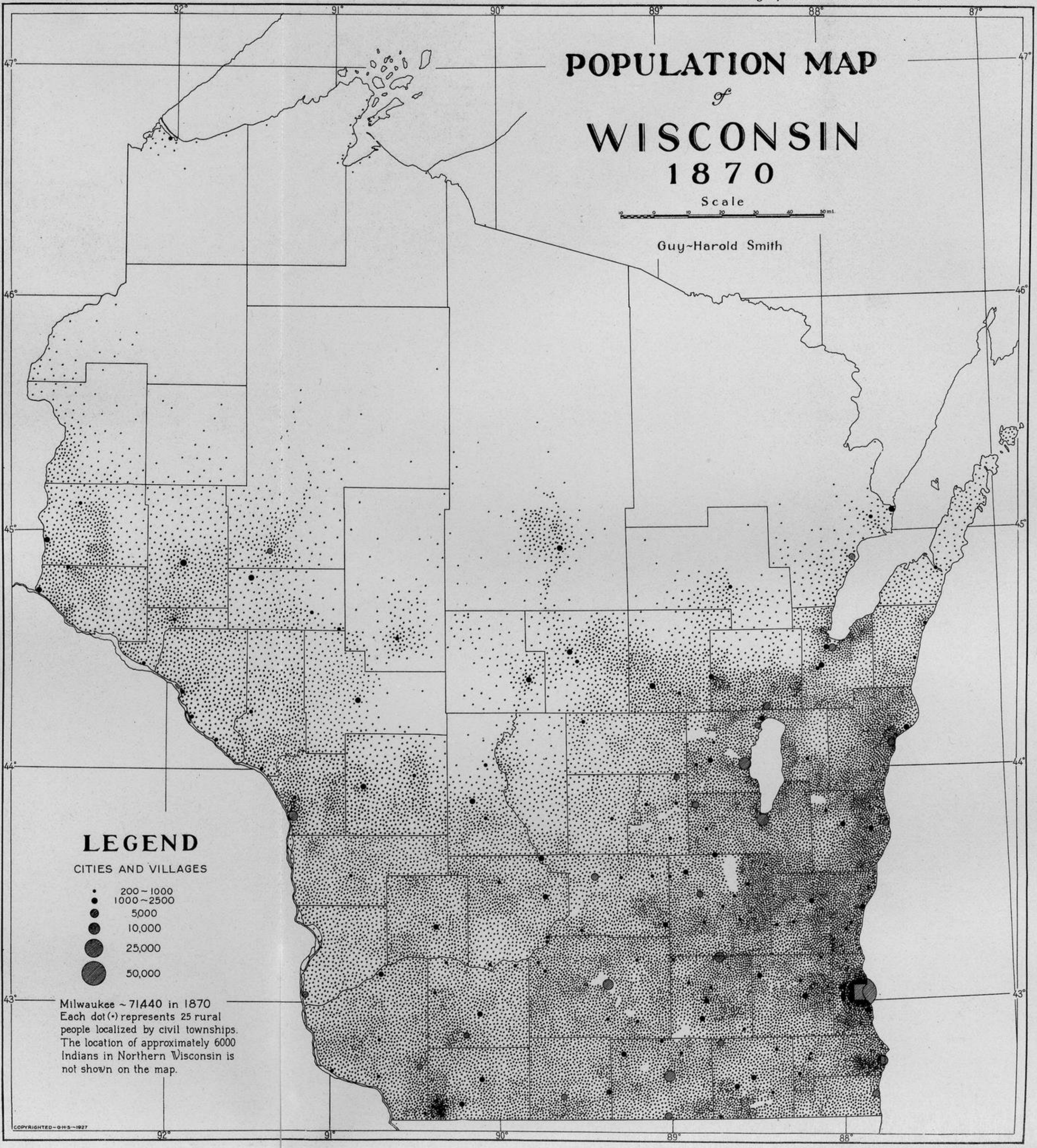
POPULATION MAP
of
WISCONSIN
1870
Scale
Guy-Harold Smith
LEGEND
CITIES AND VILLAGES
200 ~ 1000
1000 ~ 2500
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25,000
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Milwaukee ~ 71,440 in 1870
Each dot (•) represents 25 rural people localized by civil townships.
The location of approximately 6000 Indians in Northern Wisconsin is not shown on the map.
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POPULATION MAP
of
WISCONSIN
1880
Scale
Guy-Harold Smith
LEGEND
CITIES AND VILLAGES
200 - 1000
1000 - 2500
5000
10,000
25,000
50,000
Milwaukee - 115,587 in 1880
Each dot (•) represents 25 rural people localized by civil townships. The location of approximately 5000 Indians in northern Wisconsin is not shown on the map.
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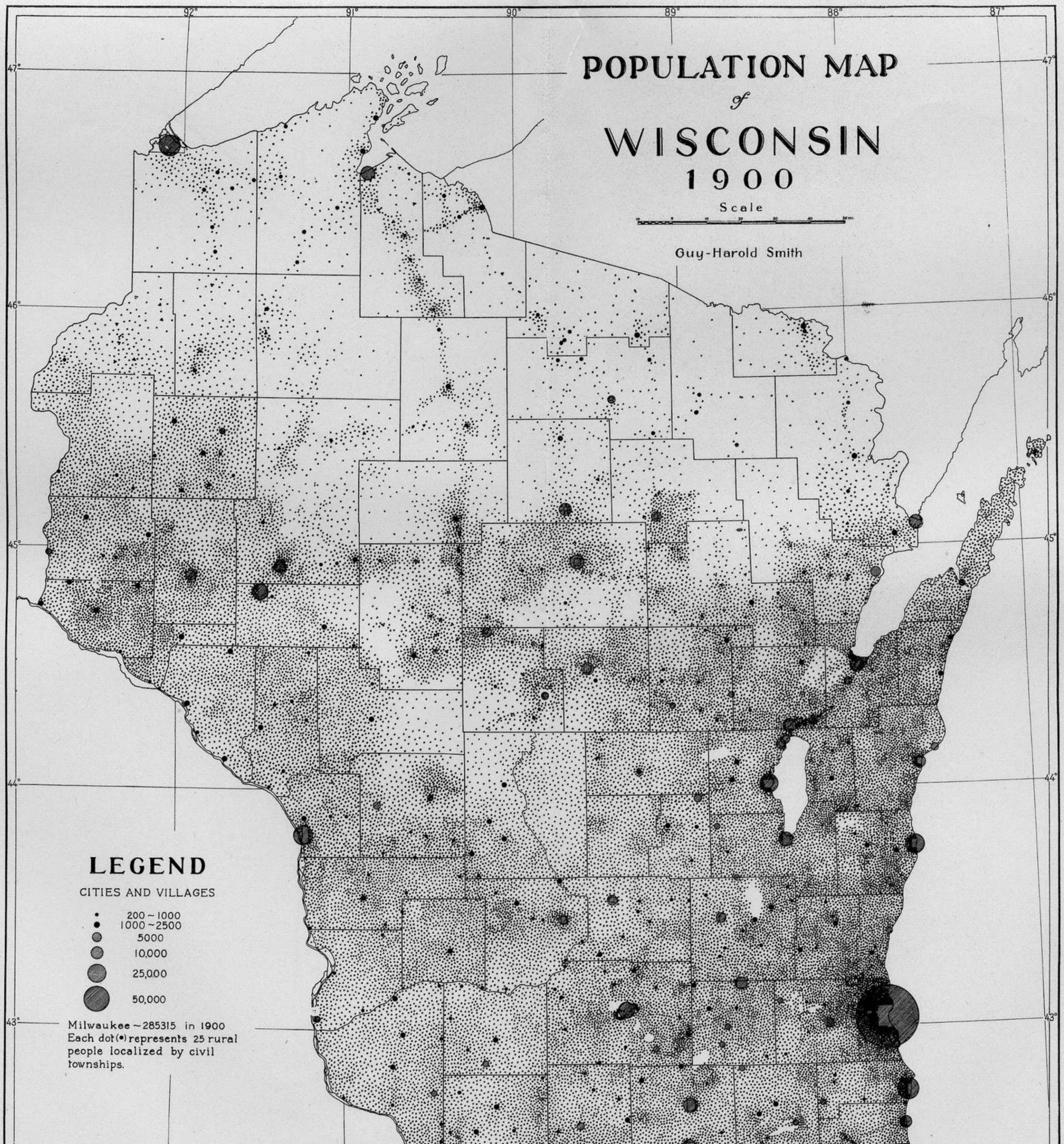

POPULATION MAP
of
WISCONSIN
1900
Scale
Guy-Harold Smith
LEGEND
CITIES AND VILLAGES
200 ~ 1000
1000 ~ 2500
5000
10,000
25,000
50,000
Milwaukee ~ 285315 in 1900
Each dot (•) represents 25 rural people localized by civil townships.
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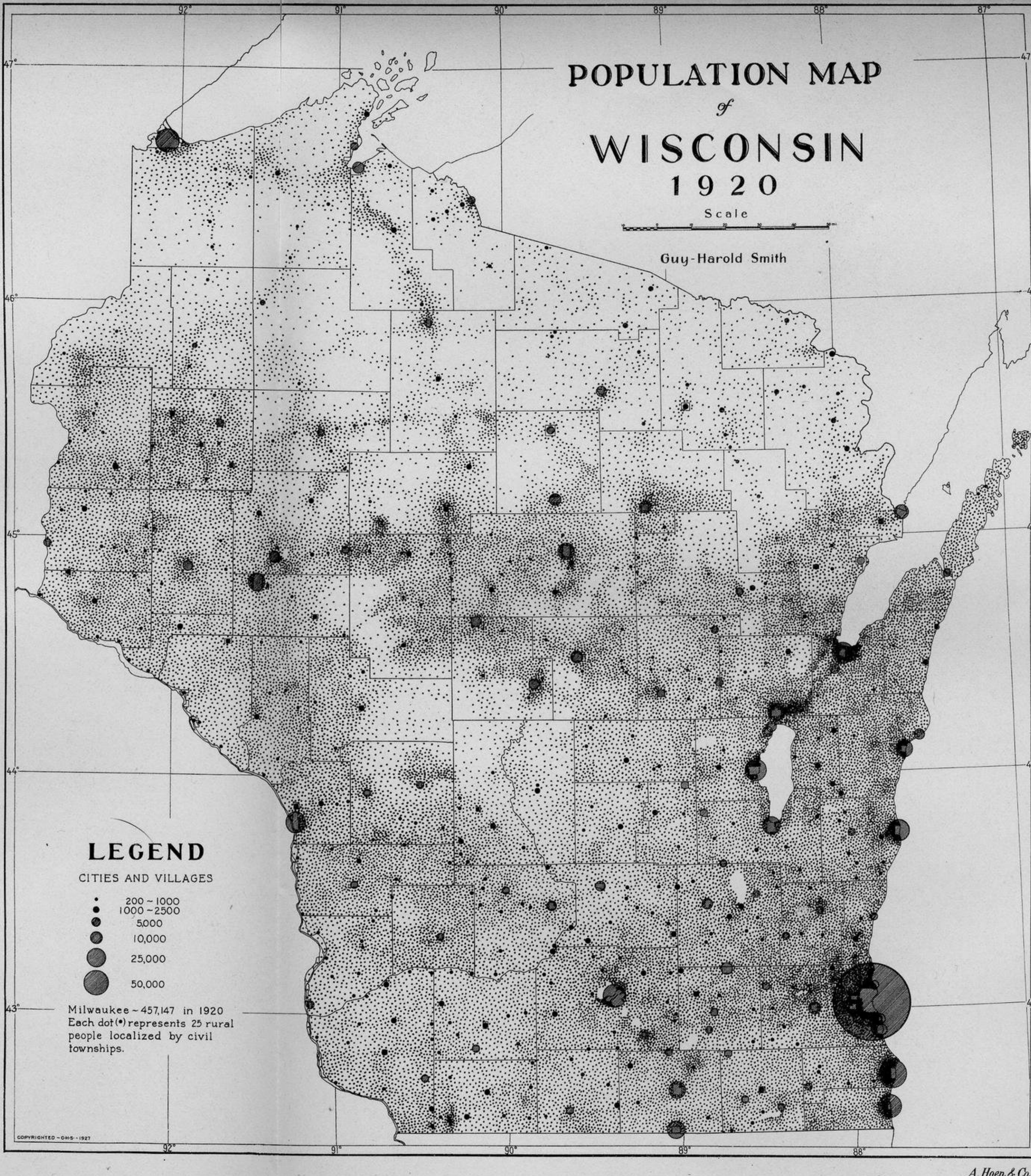
POPULATION MAP of WISCONSIN 1920
Scale
Guy-Harold Smith
LEGEND
CITIES AND VILLAGES
200 ~ 1000
1000 ~ 2500
5,000
10,000
25,000
50,000
Milwaukee ~ 457,147 in 1920
Each dot (•) represents 25 rural people localized by civil townships.
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the soil for agricultural purposes. They were tillers of the soil for they raised ". . . potatoes, maize, oats, peas, spring wheat, pumpkins, melons, cabbages, onions, and other common vegetables."[10] The ownership of the land was of certain importance for they had divided the area, according to the Canadian custom into narrow strips abutting upon the river, the pioneers' principal highway.

> The farms were ribbon-like cotes common to Canadian settlements, from one and one-half to eight arpents* wide and running back eighty arpents from the river. As a rule, only about two or three acres of this were cultivated.[11]

Prairie du Chien was the only other settlement of any significance as measured by the number of people. In 1820 there were in the settlement approximately 600 people including the 100 soldiers stationed at Fort Crawford. Like the Green Bay settlement, "The farms were the narrow fields running back from the river and there had been a common field where the inhabitants cut hay."[12] This common meadow probably was one of the open prairie areas found along the flood plain and on the terraces of the Wisconsin and Mississippi Rivers. The farm pattern shows a French Canadian influence that has persisted down to the present.

THE SETTLEMENT OF THE LEAD REGION OF WISCONSIN, 1820–1850

The active settlement of southern Wisconsin was accomplished in the three decades following 1820, This westward migration into Wisconsin may be considered as a part of the great population readjustment that was taking place in eastern United States. The sale of public lands—all of which were west of the Appalachians—reflects the movement of people from the east to the west. Sales increased rapidly after 1813, when only 140,000 acres were sold, to 1819, when 5,110,000 acres were purchased from the gov-

[10] General Ellis's Recollections, Wisconsin Historical Collections, Vol. VII, 1876, p. 216.

* Arpent (linear measure) 192 feet and 6 inches.

[11] Turner. Ibid., p. 92.

[12] Ibid., p. 92.

ernment, and then came a decrease to only 780,000 acres in 1821.[13] The westward expansion from the American seaboard into the Mississippi Valley reached its most spectacular development in the 'great migration' which brought into the Union Indiana in 1816, Mississippi in 1817, Illinois in 1818, Alabama in 1819, Maine in 1820, and Missouri in 1821. "With the admission of Missouri the great migration came to an end so far as new states were concerned, and the heavy shift of population subsided for another ten years.[14] Just as this historic movement began to abate and readjust itself to the very large area contained within the borders of the new states, Wisconsin was opened to settlement. The first movement into the territory was slow, echoing the decreasing vigor of the declining years of the great migration.

Green Bay and Prairie du Chien were the only settlements of any importance before 1820. These were occupied because of their stragetic location for commerce in furs and for the military advantages that their sites offered. These functions were not materially altered until after 1835 when the agricultural frontier approached more closely and the Indian menace had been removed.

The Lead Region. The lead deposits of the Upper Mississippi Valley had been discovered more than a century before the beginning of active settlement about 1820. Even before white man came the Indians had their 'lead diggings.' Later under the French influence, mining was stimulated, particularly by Nicholas Perrot, who purchased lead from the Indians in 1695. From that time until the end of the French régime about 1760 " . . . the lead mines were worked more or less constantly both by the Indians and by whites, who used the product to supplement the fur trade."[15] A few traders found it profitable to barter for lead, and some of the Indians willingly consented to mine rather than hunt the fur-bearing animals. This new adaptation of industry culminated in the settlement of this section after 1820.

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[13] Paxson. Ibid., p. 221.

[14] Ibid., p. 219.

[15] Louise Phelps Kellogg. The French Régeme in Wisconsin and the Northwest, p. 361.

This lead region lies . . . chiefly in Wisconsin, including, however, a strip of about eight townships of land in Iowa, along the western bank of the Mississippi, the greatest width of which strip is on the Little Mequoketa, about twelve miles from east to west, and including about ten townships in the northwestern corner of Illinois. The portion of this lead region in Wisconsin includes about sixty-two townships, or two thousand eight hundred and eighty square miles; being about one-third larger than the state of Delaware. The extreme length of this region, from west to east, is eighty-seven miles; and its greatest width, from north to south, is fifty-four miles.[16]

For more than 150 years, from the discovery of Wisconsin in 1634 until after 1800, the traffic in furs was the dominant industry. Lead had made an ineffectual appeal to the natives except when a few traders were able to stimulate the mining industry. The continual exploration revealed more and more the mineral wealth of the lead region, but the distance from the markets and the state of scientific knowledge precluded any intensive utilization of the resource. Under such conditions, the early mining, viewed from the perspective of over a hundred years, appears more as 'a promise than a performance.'

In 1804 the Sauk and Fox Indians ceded to the United States the larger portion of the lead bearing region of the Upper Mississippi Valley. The treaty among other things provided that "As long as the lands which are now ceded remain their property, the Indians belonging to said tribes shall enjoy the privilege of living and hunting upon them."[17] This stipulation was one of the indirect causes of the Black Hawk War. The pioneers who passed beyond the agricultural frontier encroached upon land used and jealously guarded by the Indians and any unlicensed intrusion was regarded as trespass.

The active mining of lead began in Illinois about 1822 near the present city of Galena, and shortly thereafter pioneer miners penetrated into Wisconsin. "In one sense the settlements were an expansion of those of northern Illinois, a widening circle of adventurers, who, not finding the 'hoped for' wealth in the mines about Galena, pushed on

[16] David D. Owen. Report of a Geological Exploration of Part of Iowa, Wisconsin, and Illinois, in 1839. Revised Edition, 1844, p. 35.
[17] Laws of the United States, Vol. 1, 1789–1815, p. 427.

into Southwestern Wisconsin to seek for richer 'leads'."[18] It was not until after 1827 when the Winnebago disturbances had quieted down that the miners became more daring. " . . . they ventured far beyond that protection which numerical strength and the defensive organizations near Galena secured."[19]

The number of people in the lead region was very difficult to determine but the report of the Superintendent of the Mineral Lands stated that,

> I am enabled to give with accuracy the number of persons at the Public Mines of Illinois only, or rather at the mines near the north boundary of that State, which are supposed to be within its limits, commonly known as the Fever River Mines, viz. On the first day of July, 1825, there were at those mines about one hundred men; on the thirty-first of December, 1825, one hundred and fifty-one men; on the thirty-first of March, 1826, one hundred and ninety-four; on the thirtieth of June, 1826, four hundred and six; and on the thirty-first of August 1826, (the date of last report,) there were four hundred and fifty-three men. You will observe the increase has been gradual, and the numbers are still augmenting.[20]

From this Illinois nucleus the settlement spread northward into southwestern Wisconsin.

As the frontier came nearer, the lead region tapped the stream of migration and deflected a part of it northward into the lands along the Upper Mississippi River.

> The time had now come when this beautiful country was to be occupied by a hardy, resolute, adventurous and persevering population. The laws which, as a rule, generally confine the migration of the human race to isothermal zones and similarity of climate, were to be set at defiance, and the emigrant from the mild climate of Tennessee, Kentucky, Missouri and southern Illinois was to exchange, the balmy and genial atmosphere to which he had been accustomed, for one in which during nearly half the year all nature is bound with icy chains and covered with its robe of snow.[21]

This explains how so many people of southern origin found their way into southwestern Wisconsin.

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[18] W. O. Blanchard. The Geography of Southwestern Wisconsin. Wis. Geol. and Nat. Hist. Survey. Bull. No. 65, p. 30.

[19] Stephen Taylor. Wisconsin—Its Rise and Progress, with Notices of Mineral Point and Richland County. Wisconsin Historical Collections, Vol. II, 1856, p. 485.

[20] House Executive Documents, 19th Congress, 2nd Session, II No. 7, p. 8.

[21] Moses M. Strong. History of the Territory of Wisconsin from 1836 to 1848, p. 118.

Influence of Geological Conditions. The mere presence of lead in Wisconsin was not the only factor which induced the migration of pioneer miners, for the mode of occurrence of the lead-bearing minerals determined to a notable degree the distribution of the inhabitants. Within the mineralized areas there is a zonal arrangement of the principal minerals.[22] Near the surface and some places at the surface, the lead ore, occupies the upper zone, occurring as large cubical crystals of galena. The fortunate circumstance that abundant ore occurred above the water table made it possible for individuals to engage in the mining industry. This created a population dispersion from the outset. Some of the miners, who later were able to purchase land for agricultural purposes were engaged in both industries, depending upon season or price of lead to determine to which they would give their services.

From Mining to Agriculture. Mining required less capital than farming. "A miner could carry practically all of the tools necessary for his work. Mining leases cost only a share of the profits."[23] Gradually there came a shift from mining to agriculture. "As agriculture developed and mining became more difficult because the surface ores had been removed, farmers turned their attention more and more to the profits of agriculture to the neglect of mining."[24] The peak of lead production was reached about 1845 after which date the amount decreased to less than half of the production of the early forties.

The Black Hawk War of 1832 removed the last menace to white man's occupancy of the lead region. At first the semi-nomadic trader stimulated the Indians to search for furs. Over this primitive occupation the miner overlaid a new industry characterized by the intensive search for lead, and localized effort replaced the extended activities of the hunter and trader.

The coming of the farming element after 1832 added

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[22] U. S. Grant and E. F. Burchard. Description of the Lancaster and Mineral Point Quadrangles (Wisconsin-Iowa-Illinois). U. S. Geol. Survey, Folio No. 145, p. 12.

[23] Blanchard. Ibid., p. 66.

[24] Selma L. Schubring. A Statistical Study of Lead and Zinc Mining in Wisconsin. Trans. of the Wis. Acad. Sci., Arts and Let. Vol. 22, 1926. p. 15.

hundreds to the population, and the concentrated occupancy of the land completely displaced the aborigines and erased their culture from the land that had maintained them for centuries. Cultural conditions of another order displaced the old when white man replaced the red man.

The land with its fertile soil and the extensive prairie areas was capable of yielding crops—particularly wheat—that would equal those of other states. According to Owen's report the land of this section was originally about 37 per cent prairie and 63 per cent woodland.[25] This combination of woodland interspersed with prairie was a fortunate circumstance for the early farmers, but many did not realize it.

The Land Survey. It is significant that southern Wisconsin was surveyed from the west toward the east. The land survey was begun in 1833 by the erection of the Fourth Principal Meridian through the heart of the lead region where a nucleus of permanent settlers required a title to their land held previously by leases or by 'squatters' rights.

The survey initiated a speculation in land, particularly in sections adjacent to the mineral lands reserved from sale. Probably two thirds of the land sales prior to 1837 were to speculators.[26] The 'specie circular' issued at the stipulation of President Jackson ended speculation. The President desired to prevent public lands from falling into the hands of capitalists who might do injury to settlers in search of new homes.[27] Speculation was curtailed, and the settlers continued to press against the cutting edge of the frontier.

Statistical Measure of Settlement. The first reliable quantitative data on population, other than estimates and partial enumerations in Green Bay and Prairie du Chien, are contained in the United States Census of 1830 which gives a population of 3,245 for the three Wisconsin Counties, viz, Brown County 964, Crawford County 692, and Iowa County 1,589. Almost half of the people were in Iowa County,

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[25] Owen. Ibid, p. 145.

[26] Strong. Ibid., p. 217.

[27] Senate Document No. 15 of December 14, 1836. 24th Congress Second Session.

which included the lead region, and the remainder were in the two long established posts of Green Bay and Prairie du Chien.

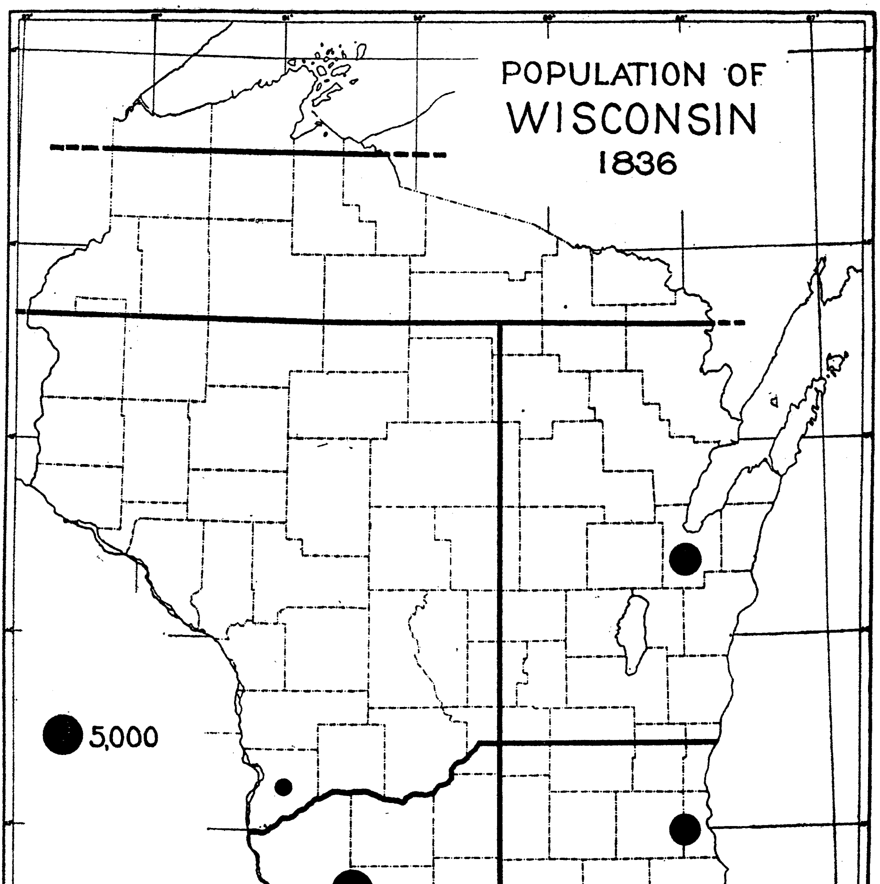

FIG. 2. The population of Wisconsin in 1836. (Data from the First Census of Wisconsin Territory, taken in July 1836.)

Wisconsin was organized as a Territory in 1836 and the next census[28] taken in July of that year gives the population as 11,683. Brown county had 2,706 inhabitants, Crawford

[28] The Territorial Census for 1836. Wis. Hist. Coll. Vol. XIII, 1895, pp. 247-270.

850, Iowa 5,234, and Milwaukee 2,893. The lead region continued to be the most densely settled section.

The two counties of Grant and Iowa included one fourth of the population of the Territory. But with the rapid

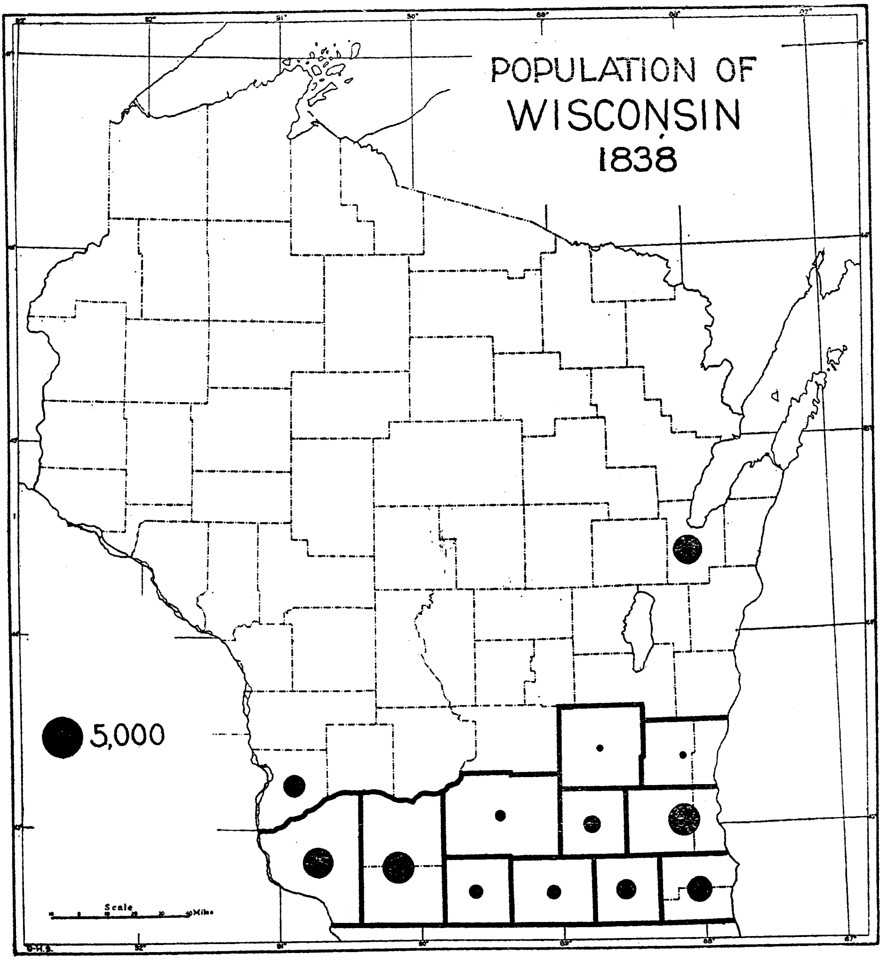

FIG. 3. The population of Wisconsin in 1838, two years after the formation of the Territory. (Data from Clark S. Matteson, An Illustrated History of Wisconsin, pp. 259–260.)

growth of population in eastern and south central part of the Territory the lead-producing counties had only 17 per cent of the total in 1846, and by 1847 this was decreased to

13 per cent. Lead mining was declining but settlers continued to come into the area. The gold rush to California attracted many miners but the influx of agriculturalists prevented a decrease in population.

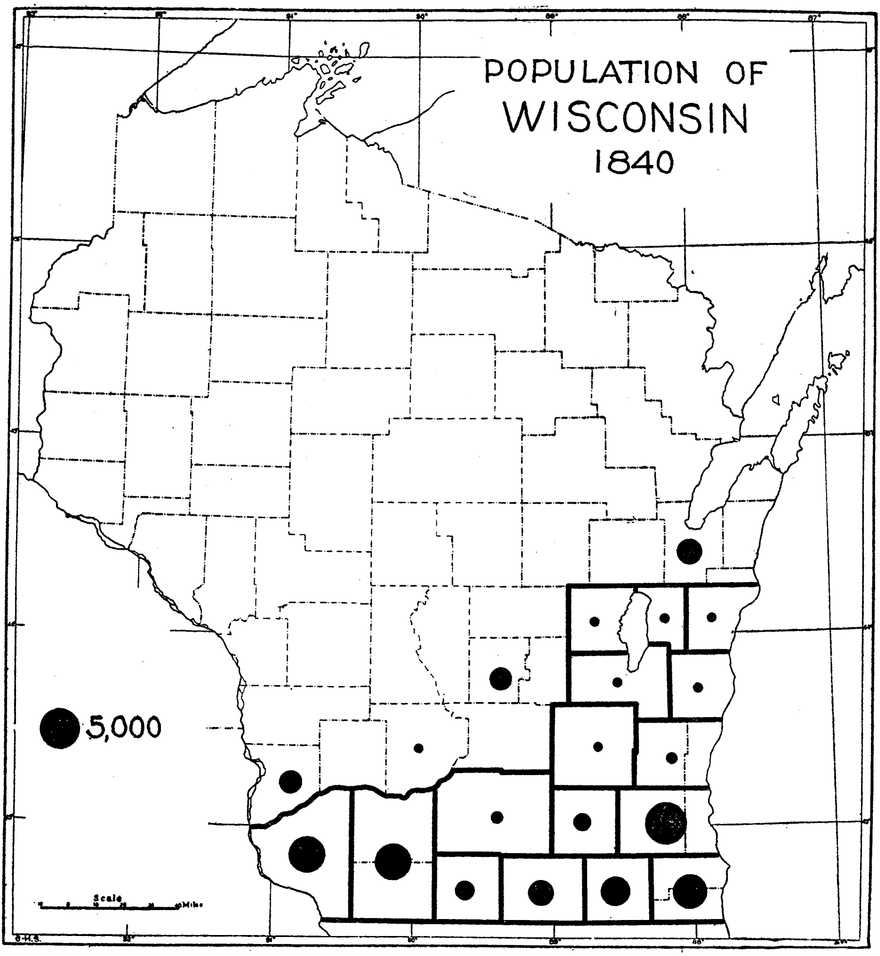

FIG. 4. By 1840 the frontier had crossed the southeastern quarter of Wisconsin. (Data from the Journal of the Convention, January 3, 1848, pp. 156–163.)

With the exhaustion of the easily mined lead deposits, the lands previously reserved from sale were placed upon the market. Congress provided that the President be

" . . . authorized, as soon as practicable to cause the reserved lead mines and contiguous lands in . . . Wisconsin . . . belonging to the United States, to be exposed to sale, in the same manner that other public lands are authorized by law to be sold . . ."[29] By the time Wisconsin was admitted to the Union in 1848 the population of the lead region was approximately 30,000. In 1825 there were only a few score in the region, and in 1836 when Wisconsin became a Territory the number was only 5,234, but rapid settlement in the middle forties changed the lead region into an agricultural section.

THE SETTLEMENT OF EASTERN WISCONSIN 1832 TO 1850

After 1832 the southeastern part of Wisconsin began to tap the stream of western migration and by 1850 most of the area from Lake Michigan westward to the lead region, and northwestward toward the Fox River was completely settled, and the frontier moved on. The United States Census for 1850 gives in detail the population of the state, and the map prepared from these data pictures graphically the distribution of the inhabitants. The map shows the rather even film of rural population thinning out along the frontier, and the concentration of the people in urban communities where the advantages of site or situation provided the bases for the agglomerations.

The frontier of settlement, by 1850, was approaching, and in a few places had crossed the Fox and Lower Wisconsin Rivers. That indefinite boundary between the settled and the unoccupied land was a progressively shifting agricultural frontier. The westward and northward movement of this frontier up to 1850 had left behind it over 90 per cent of the total population, or 287,730 settlers, including 37,225 in the three lead mining counties of the southwest. The remaining 17,660 people were in the ten or more northern wilderness counties.

The Beginning of Settlement. The settlement of southeastern Wisconsin after 1832 is epochal. The lead region

[29] U. S. Statues at Large. Vol. IX July 11, 1846, p. 37.

was first settled by a final wave of the great migration, but southeastern Wisconsin was peopled by a current from the Jacksonian migration which started about 1832, so far as Wisconsin is concerned, and reached its crest about

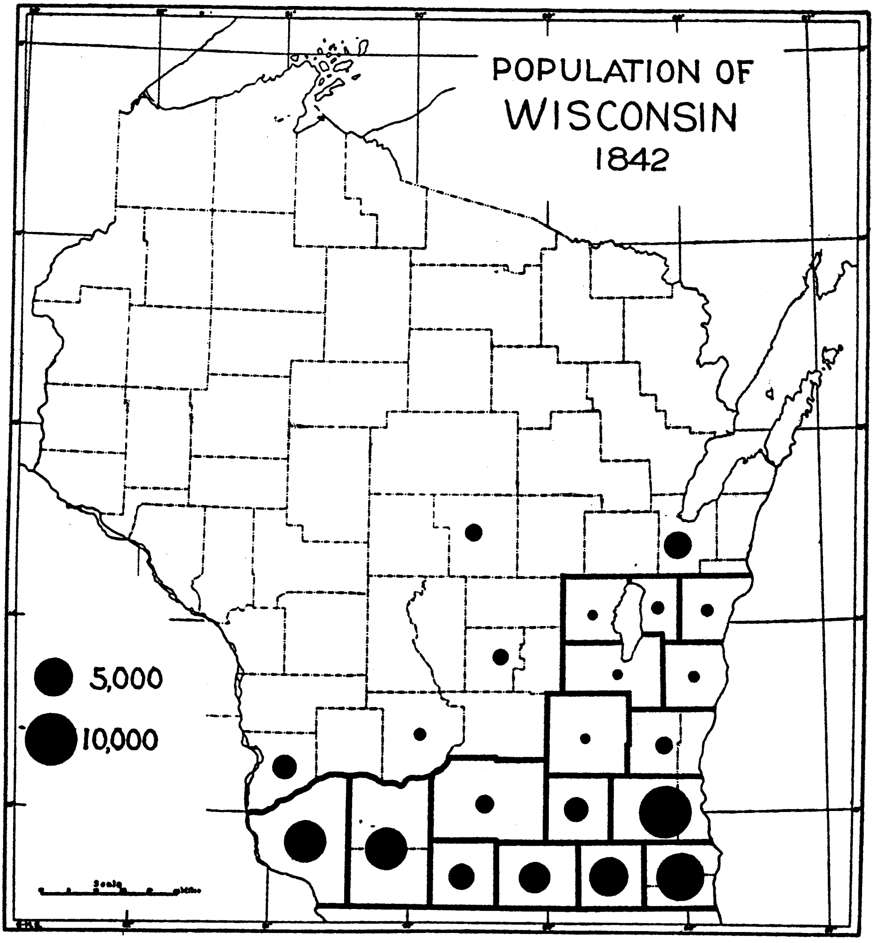

FIG. 5. Between 1840 and 1842 the population of Wisconsin increased from 30,945 to 44,478. (Data from the Journal of the Convention, January 3, 1848, pp. 156–163.)

1837; but for many years thereafter the irresistable human horde sought the newly opened lands. Most of the land was entered either by speculators or by the actual settlers in the years of 1836, 1837 and 1838. Even after 1840 there was considerable land to be settled, but the major portion of the government lands had been sold. Resale by speculators permitted an intermingling of new settlers with those who had preceded them by only a few years.

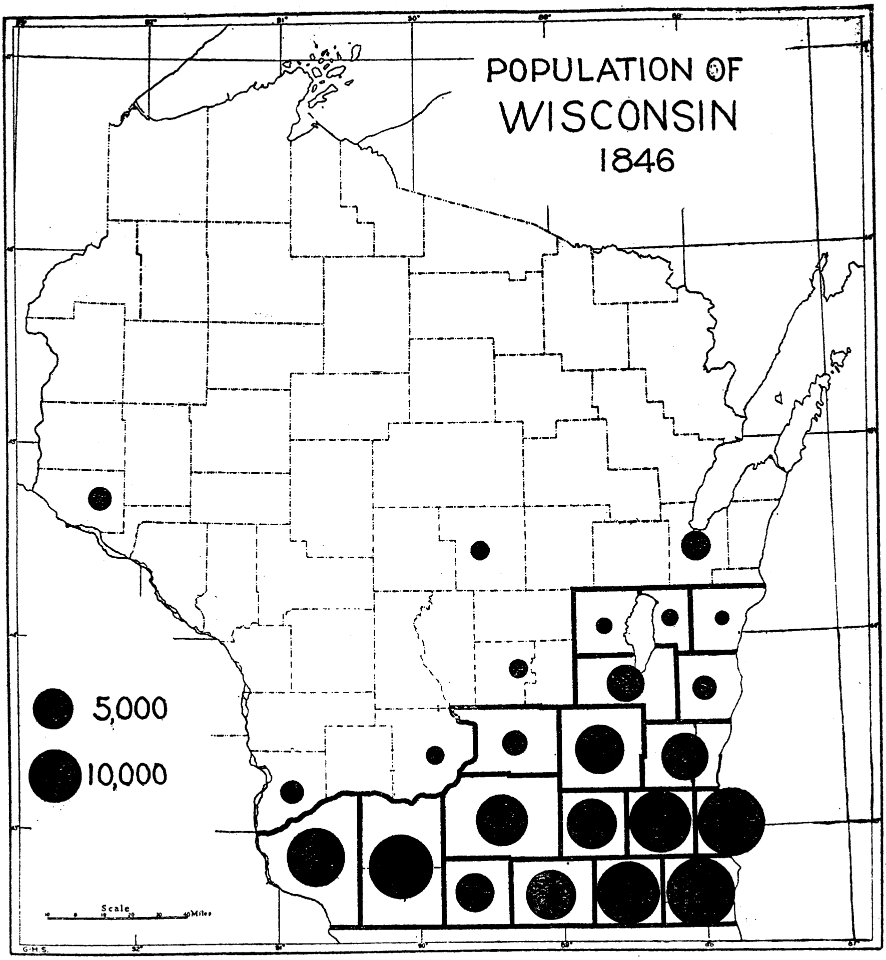

FIG. 6. By 1846 southern Wisconsin had a population of approximately 150,000. (Data from the Journal of the Convention, January 3, 1848, pp. 156–163.)

Just as the explorers and traders sought the waterways in their penetration of Wisconsin, the settlers were guided in their great 'trek' to the new lands. They were ever mindful that to depart from the waterways was to find as obstacles, swamps and forests that were traversed only with great effort. The first settlers into the lead region came from the south and created a nuclear settlement that expanded eastward. There were more people from Kentucky, Tennessee, and Missouri in the lead region in 1850 than in all the remainder of the state. Southeastern Wisconsin drew homeseekers from New York, New England and other eastern states, thus the movement into Wisconsin after 1832 was an along-the-parallels migration.

The new settlers came by way of the recently completed Erie Canal and the Great Lakes to the western shore of Lake Michigan. From the Ohio Valley many descended the Ohio River to Cincinnati where they deserted nature's highway and come across Indiana and Illinois to Wisconsin. Enroute they were joined by natives of the states they were traversing until the newcomers represented a homogeneous mixture of native Americans and their immediate foreign born ancestors. Among the immigrants from Indiana and Illinois, came many people, who had participated in the great migration.

The manuscript census[30] for 1850 records many families in which the father and mother were born in New York, and two or three children in Indiana, and two or three more in Wisconsin. Similarly many of the foreign born came westward as far as Ohio and then moved on to Wisconsin after a few years. The peopling of Wisconsin had become a psychological movement, and the news accounts in the eastern papers accelerated the migration.

Schafer, writing about the southeastern section of the state, notes that,

> The movement of settlers into the region was well started by the spring of 1836. Most of the emigrants came by sloop or steamer on the lakes, debarking at Milwaukee, Racine, or Kenosha, or else at Chicago whence they made their way up the coast.[31] (See figures 2, 3, 4, 5, 6, and 7)

The Land and Its Utilization. Southeastern Wisconsin is almost entirely within the physiographic province called

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[30] The manuscript census reports for 1850, 1860, and 1870 have been deposited in the Library of the State Historical Society of Wisconsin.

[31] Joseph Schafer. Four Wisconsin Counties, Prairie and Forest, p. 64.

by Martin "The Eastern Ridges and Lowlands."[32] (See fig. 8). This region is underlain by eastward dipping sedimentary formations of the Paleozoic system. In pre-gla-

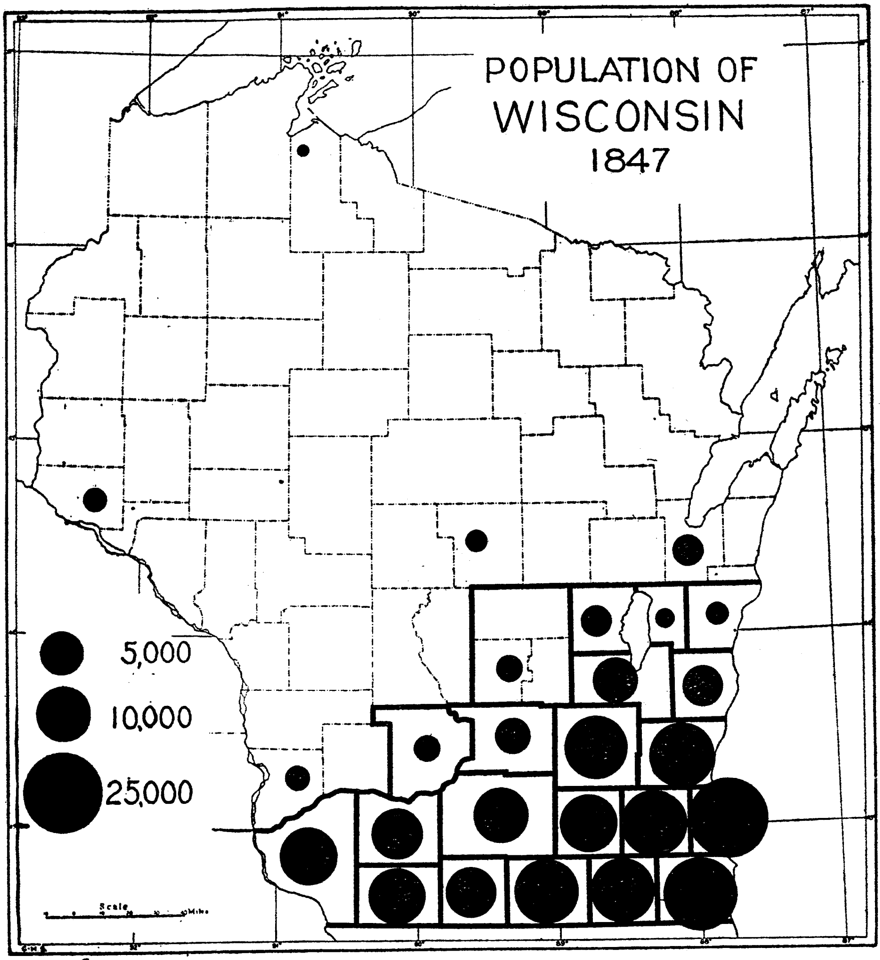

FIG. 7. In 1847, on the eve of the admission of Wisconsin into the Union, the population was 210,546. (Data from the Journal of the Convention, January 3, 1848, pp. 156–163.)

cial time the area had been maturely dissected into a relief of approximately 300–500 feet. The major topographic features are the cuestas developed upon these slightly dip-

[32] Lawrence Martin. The Physical Geography of Wisconsin, Wis. Geol. and Nat. Hist. Survey, Bull. 36, 1916, pp. 197–298.

ping sedimentary rocks. Superposed upon the maturely dissected cuesta landscape is a veneer of glacial drift which has reduced the relief and replaced the erosional topography with a depositional topography. However, along the escarpment margin of the cuestas the drift is thin and the bed-rock makes its influence felt through the mantle of drift.

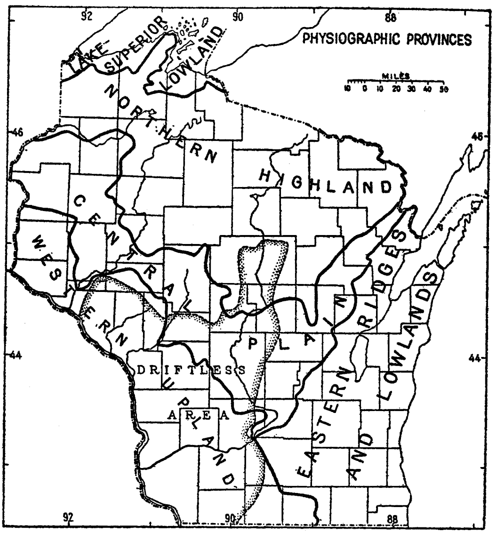

FIG. 8. The physiographic provinces of Wisconsin. (After Martin.) (Courtesy of the Geographical Review published by the American Geographical Society of New York.)

In the southern tier of counties from Lake Michigan to the Mississippi there were originally extensive prairie areas. Northward the prairies were smaller and not so closely spaced. Around the prairies were the 'oak openings' and the more densely forested areas which took on a distinctly primeval aspect farther north.

The distribution of improved land in 1850, and particularly the number of acres per capita indicate with fair accuracy the progress of settlement in Wisconsin. Rock County ranked first with 143,235 acres; Walworth was second with 116, 750 acres; and Waukesha third with 105,269. The counties having over 5 acres of improved land per capita were Rock, Walworth, Dodge, and Green. In general the amount of improved land decreased rapidly toward the frontier and particularly northward along the lake shore where the heavy forests effectively retarded the improving of the land.

Washington County had 2.2 acres of improved land per person, Sheboygan 1.6 acres, and Manitowoc only 0.3 acres. Similarly there was at that time a concomitant relationship in the number of people in these three counties. Washington had a population of 19,485, Sheboygan 8,379, and Manitowoc only 3,702.

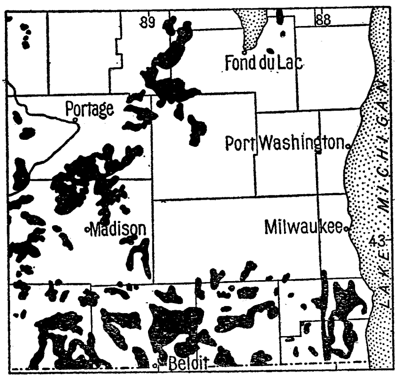

FIG. 9. The prairie areas—in black—in southeastern Wisconsin. (After Martin.) (Courtesy of the Geographical Review published by the American Geographical Society of New York.)

This region to the east was heavily forested and the conversion of the unimproved to improved land required years of strenuous labor; and then the stumps remained for a generation, hindering the cultivation of the land.

The People. The value of any area for agricultural purposes is largely determined by the conditions of the natural landscape, soil, climate, and proximity to other areas which offer opportunities for exchange of products and ideas. But under almost ideal environmental conditions a region might remain undeveloped. "The lands of any country are important for the human opportunity they represent. The use which is made of them depends upon the people who come into their possession."[23]

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[23] Joseph Schafer. A History of Agriculture in Wisconsin. p. 23.

In southeastern Wisconsin there has developed a sectionalism where the conditions of the physical landscape were more or less uniform originally, except for a difference in the natural vegetation. The southern part of this area was characterized by the open oak forest with the extensive prairies. (Fig. 9). Just to the north of the southern tier of counties was a hardwood forest of maple, and some oak and beech. Along the eastern coast a strip of conifers began just north of Milwaukee and extended northward, becoming wider until it embraced all of Door Peninsula.

In the settlement of southeastern Wisconsin, there was enacted what may be called an experiment in historical geography. The southern division was settled by the Yankees and the British and the forested section by the Teutons. When the Yankees settled the southern row of counties they did not, for long at least, shun the prairie lands as has often been stated. However, it is true that certain prairie sections were not entered until a few years after the wooded areas had been sold. Schafer has shown

> . . . that the Yankee settlers in a prevailingly prairie township of Racine County took up first every acre of forested land, together with the prairie lands and marsh lands adjoining the woods, while they shunned for some years the big, open, unsheltered prairie where farms would be out of immediate touch with the woods.[34] (Fig. 10).

These homeseekers were not destitute, and with the credit extended to them by their friends and relatives, and because of a tradition distinctly British in origin, the purchase of a farm was looked upon as a method of creating an estate. Large farms were the rule.

The number of Germans in Wisconsin before 1850 formed an important nucleus which determined the population conditions in the forest section of eastern Wisconsin (Fig. 11). The 38,064 Germans made a noteworthy contribution to the vital statistics.

> About 30,000 old Lutheran subjects of Prussia . . . are shortly to come over and settle in these United States. It is a religious movement, these people preferring the good old orthodox doctrines to the modern philosophy of Berlin. There are men of very large for-

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[34] Joseph Schafer. The Yankee and the Teuton in Wisconsin. Wisconsin Magazine of History, Vol. VI, Dec. 1922, p. 9.

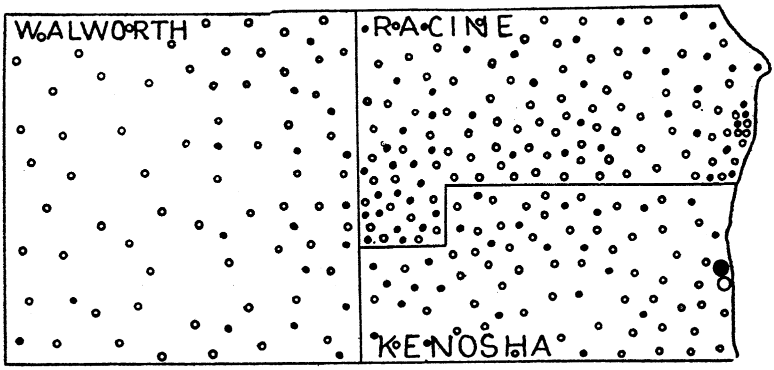

FIG. 10. The number of German inhabitants in Racine, Kenosha, and Walworth Counties in 1850 was small. The British and the Yankees were the predominating population groups. Each symbol represents 25 inhabitants; the dots, German and the circles, British. (Data from a hand count made from the 1850 manuscript census for the State Historical Society of Wisconsin by M. M. Quaife and an assistant.)

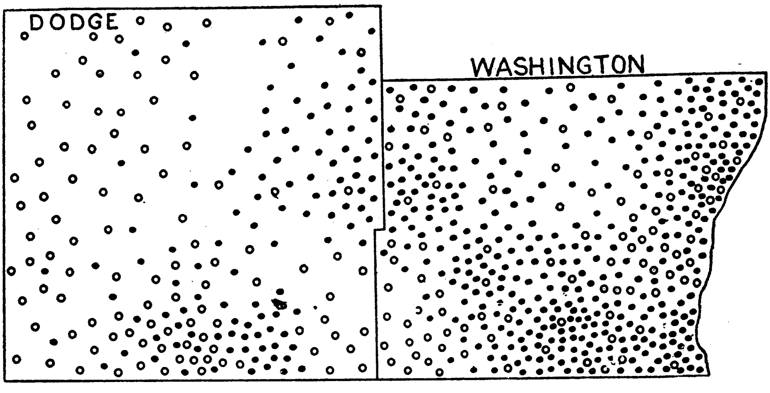

FIG. 11. The distribution of German and British born settlers in Dodge and Washington Counties in 1850. Each symbol represents 25 inhabitants; the dots, German, and the circles British. Note the general decrease in the Germans westward from Lake Michigan. In 1850 Washington County included the present Washington and Okaukee Counties. (Data from a hand count made from the 1850 manuscript census for the State Historical Society of Wisconsin by M. M. Quaife and an assistant).

tunes among them; old German noblemen whose pedigrees date back to the thirteenth century. They will make excellent western farmers, and are about to settle in Wisconsin—the coolest spot they can select.[35]

These German immigrants coming to America took the densely wooded areas. Why this selection? Schafer gives an answer in the following statement.

It is at bottom a question of economic ability, not of personal or racial tastes. The poor immigrants and the poorer natives also, with, of course, many exceptions, settled in the woods because they could not afford to encounter the risk of taking an ideal farm in the 'Congress Land' districts, nor could they afford to buy such land from speculators or from farmers. They took what was at hand, the heavily wooded lands avoided by persons who were in position to pick and choose. In many cases they might have found lands on the open prairies, which . . . were taken later than the other lands even by Americans who had some means. But the person without means would have been helpless in such a situation. He would need money to buy lumber both for building and for fencing, while in the timber his personal labor supplied these essentials, without cost, in the process which at the same time cleared his land.[36]

The Germans who settled in the rural communities generally purchased small farms, from 40 to 80 acres, and this had the effect of creating a dense rural population in this area which was originally a maple forest. And after three-quarters of a century the small farms are common, in many of the counties averaging less than a hundred acres. (Fig. 20). No other part of Wisconsin has so dense a rural population as this German settled section.

In a generation or two the forest had been removed and the two sections were essentially the same. Both the German settled section northwest of Milwaukee and the Yankee settled strip along the southern tier of counties present a cultural landscape of beauty and prosperity. This type of controlled geographical experiment illustrates the importance of nationality, a social element, in influencing the relation of man to his habitat.

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[35] Niles' National Register. June 17, 1843, chronicle from the St. Louis Republican June 7.

[36] Joseph Schafer. A History of Agriculture in Wisconsin, p. 39.

The Northward Movement of the Frontier in Wisconsin 1850–1880

In the period from 1850 to 1880 the movement of population into Wisconsin completed the agricultural settlement of that part of the state underlain by the Paleozoic sediments. In central Wisconsin the earlier glaciated and driftless portion of the older crystalline area also received a large number of people, and across the heavily forested Northern Highland thin threads of settlements followed the

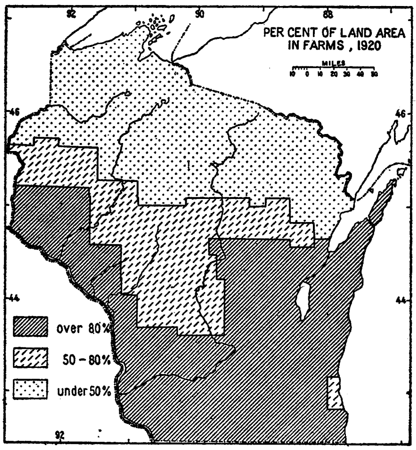

Fig. 12. Land areas in farms, 1920. (Courtesy of the Geographical Review published by the American Geographical Society of New York).

rivers, roads and railways leaving isolated blocks of untouched wilderness. By 1880 the frontier of settlement had crossed Wisconsin, but within the state there remained wilderness sections, around the periphery of which, the frontier slowly encroached and penetrated.

The frontier seemed to be pivoted at Green Bay and swept northward more rapidly across the Western Upland. As it approached the densely forested upland to the north the settlers departed from the deployed formation to one of concentrated invasion along important salients. This single-file invasion has had the effect of leaving sections of virgin forest and cut-over land unoccupied down to the present time.

With the extinction of the Indian titles, the lumbermen with axe and saw overlaid a new culture on the site of the fur-trading industry, which had declined after 1834 until it was of little importance, and the roving hunters and traders were replaced by more sedentary, yet transient, pioneers. Lumbering became the dominant industry and the removal of the forest prepared the way for the agricultural settlers who were soon to follow.

Wisconsin has been crossed by a succession of frontiers, but due to the time of settlement the sequence has not been the same in all parts of the state. Generally speaking the earlier settled sedimentary Wisconsin was crossed by the frontier of the hunter and trader in the period from 1634 down to 1820. This frontier prepared the way for the miner in the southwestern part of the state. In less than twenty years the pioneer agriculturists occupied the southern part of Wisconsin, and along the frontier the farmers exploited the soil by raising wheat to the exclusion of soil conserving crops. And finally a diversification of agriculture,—supplemented at first by dairying, and later made subservient thereto—slowly advanced a new kind of frontier across the land.

The westward movement involved the wasteful removal of the forest to prepare the land for agriculture. This was the guiding principle as the frontier marched westward across the Old Northwest. But as the frontier advanced northward into the highlands of the northern peninsula of Michigan, Wisconsin, and Minnesota, the destruction of the forest did not leave in its wake farm land of such high potential value as in the hard-wood forests to the south.

The settlement of the prairie areas of the Mississippi and Missouri Valleys created a demand for lumber which the Upper Lakes country was made to supply. Northern Wisconsin with Michigan and Minnesota became commercial lumber areas where the removal of the forest for its lumber was the principal motive in clearing the land and not a preparation for agriculture. In fact the forest was gone before much of the land was wanted for agricultural purposes.

In spite of more invulnerable obstacles in the creation of a livable habitat out of the new lands the settlements in Wisconsin " . . . moved at least one degree farther north . . ."[37] in the decade between 1850 and 1860.

The Settlement of Western Wisconsin. In 1850 there were more than 9,000 people in western Wisconsin beyond the lower Wisconsin River. Most of these were in Sauk, Richland, and Crawford Counties and constituted an advance guard of homeseekers who were pushing northwestward to settle the available lands of the Western Upland and the adjacent Central Lowland. Settlement progressed in a wave-like formation, the crest of which swept northward in the three decades from 1850 to 1880.

The 9,000 of 1850 were increased to over 100,000 in 1860. The decade of the sixties added 98,645, bringing the total to over 200,000. By 1880 the population of this part of Wisconsin exceeded 300,000. Each of the three decades added 100,000, and, in effect, accomplished the settlement of the area, for in the decade of the eighties the increase had dropped to about 75,000. The frontier of the farmer had passed beyond the Western Upland into the crystalline Northern Highland.

As previously stated western Wisconsin was settled by a wave of homeseekers who pushed northward after 1850. Sauk, Richland, and Crawford Counties were peopled in the decade of the fifties; Vernon, Monroe, and La Crosse Counties constitute the section that was settled in the sixties; and in the decade of the seventies the wave of settlement had advanced to the latitude of Pierce and St. Croix Counties. (See population maps for 1850, 1860, 1870 and 1880).

The Settlement of Central Wisconsin. The frontier passed very lightly across the sandy plain of central Wisconsin. By 1880 the stream of settlers had pushed beyond the plain into the southern segment of the Northern Highland. The several counties that lie wholly or partially in the sand country present an aspect of a flat plain with poor sandy soil unsuited to intensive agricultural development.

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[37] U. S. Census, Population, 1880, p. XVIII.

In 1850 the population of this section was about 10,000. In 1860 Adams County which lies entirely in the plain had 6,492 inhabitants; in 1870 the number had increased to 6,601, and by 1880 the number was 6,741. Settlement was practically complete by 1870, and later enumerations showed only slight increases, except in the strategically situated cities and villages, and an increment in numbers was due essentially to the excess of births over deaths. Emigration from the area had not yet become a population readjustment.

The Settlement of Northeastern Wisconsin. The northeastern part of the state that was settled in the three decades from 1850 to 1880 included Brown, Door, Kewaunee, and Outagamie Counties, and approximately half of Marinette, Oconto, and Shawano Counties. Much of this area was either pine covered or there was an important mixture of the conifers with the hardwoods. Door Peninsula was more primeval in aspect than the section farther south, and consequently, offered a more hostile environment to the incoming settlers. Furthermore, the retarded settlement in the peninsula was due to its location as a projection out into the lake, and in effect it was passed by.

This section bordering Green Bay had about 35,000 inhabitants in 1860. By 1870 the number had doubled, and the enumeration of 1880 gave these seven counties a total of nearly 120,000. The following table shows the growth of population in two lake shore counties.

	1860	1865	1870	1875	1880
Sheboygan	26,875	27,671	31,749	34,021	34,206
Manitowoc	22,416	26,762	33,369	38,456	37,505

These counties did not fill up so completely as some of the southern sections largely because of the retarding influence of the forests.

Brown and Outagamie Counties with the more valuable agricultural lowland and the advantages of urban sites along the Lower Fox River received the major portion of the settlers in the northeastern part of Wisconsin. Brown County increased from 11,795 in 1860 to 34,078 in 1880, and in the same period the number in Outagamie County increased from 9,587 to 28,716, and because of the advantages in this lowland, continued their growth after 1880.

Marinette and Oconto Counties were still in the pioneer stage of their settlement in 1880. This is the only section of sedimentary Wisconsin that was not completely settled by agriculturalists by 1870. There is no doubt that the pine forest operated as a deterrent to agricultural settlement. One writer describes the pine lands as follows:

> There is comparatively very little farming done in the lumber region. The country is rugged; there are few roads; and to man in search of a home it looks like the work of a lifetime to acquire a foothold there. There are fairer fields; there are softer climates; there are roads and school-houses, and more social advancement, farther southward. So he turns away; and so we go on, year after year, hewing down our wealth of timber and carrying it off to keep up the prosperity of other states.[38]

The Settlement of Northern Wisconsin. That part of Wisconsin, which lies north of the northern boundary of Clark, Marathon, and Shawano Counties, was only sparsely settled prior to 1880. In 1850 approximately 500 pioneers had ventured into this region; in 1870 there were still less than 2,000; but by 1880 the number was approaching the 10,000 mark. Before 1880, that part of Wisconsin underlain by the ancient crystalline and associated rocks had not participated in the active settlement of Wisconsin. Only a scant 10,000 were in the region in 1880, but ten years later the population was over 85,000, so the settlement of that section of Wisconsin north of the latitude of the northern boundary of Marathon County belongs to a later period than the interval required for the agricultural occupation of the crescent-shaped area north of the Lower Wisconsin and Fox Rivers.

A small segment of the crystalline area embraced in Clark, Marathon, Portage, Waupaca and Wood Counties was settled before 1880, and from the standpoint of time of settlement belongs with the regions to the south rather than the more northern highland wilderness.

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[38] Charles D. Robinson. The Lumber Trade of Green Bay. Trans. Wis. State Agr. Soc. 1858–59, pp. 404–405.

Population Changes in Older Wisconsin. Behind the frontier there was an intensification that tended toward filling the vacant spaces. The three counties in the lead region increased very slowly from 1850 to 1870 when there began a decrease in population. From 1870 to 1880 Grant County decreased 127, Iowa 916, and La Fayette 1,380, an aggregate decrease of 2,423 people. Lead, and after 1865 zinc, had attracted into the region more people than the mineral and agricultural resources could support, and emigration became a necessary population readjustment.

In southeastern Wisconsin the decade of the fifties was a period of active settlement. Several counties, particularly those nearer the frontier, doubled in population. Dane County increased from 16,639 in 1850 to 43,922 in 1860; Dodge went from 19,138 to 42,818; Fond du Lac from 14,-510 to 34,154; Manitowoc from 3,702 to 22,416; Winnebago from 10,167 to 23,770; and Milwaukee from 31,077 to 62,-518. In the decade of the fifties, older Wisconsin, or that section south of the Lower Wisconsin and Fox Rivers, received two-thirds of the people who contributed to the population increase. Not a single county showed a decrease.

Between 1860 and 1870 the increase continued, but the section had less than half of the increase for the state. The three counties of Kenosha, Ozaukee, and Walworth showed a decrease in population. In the ten year interval from 1870 to 1880 the increase in population in the state was 260,827 and older Wisconsin accounted for less than a quarter of the total gain. It is obvious that the cutting edge of the frontier was the site of the greatest increments to the total population.

Population Growth and Readjustments 1880–1920

The history of the settlement of Wisconsin prior to 1890 is a narrative of human conquest of unoccupied lands. But toward the end of the last century the new lands of Wisconsin had been so reduced in area that the frontier was practically gone except in the more remote sections to the north. In the United States Census for 1890 it is recorded that the "Lumbering and mining interests have practically obliterated the wilderness of Michigan and have reduced that of

Wisconsin to less than one-half of its former area."[39] This decrease in the wilderness was accompanied by a reciprocal increase in land in farms contingent upon the northward

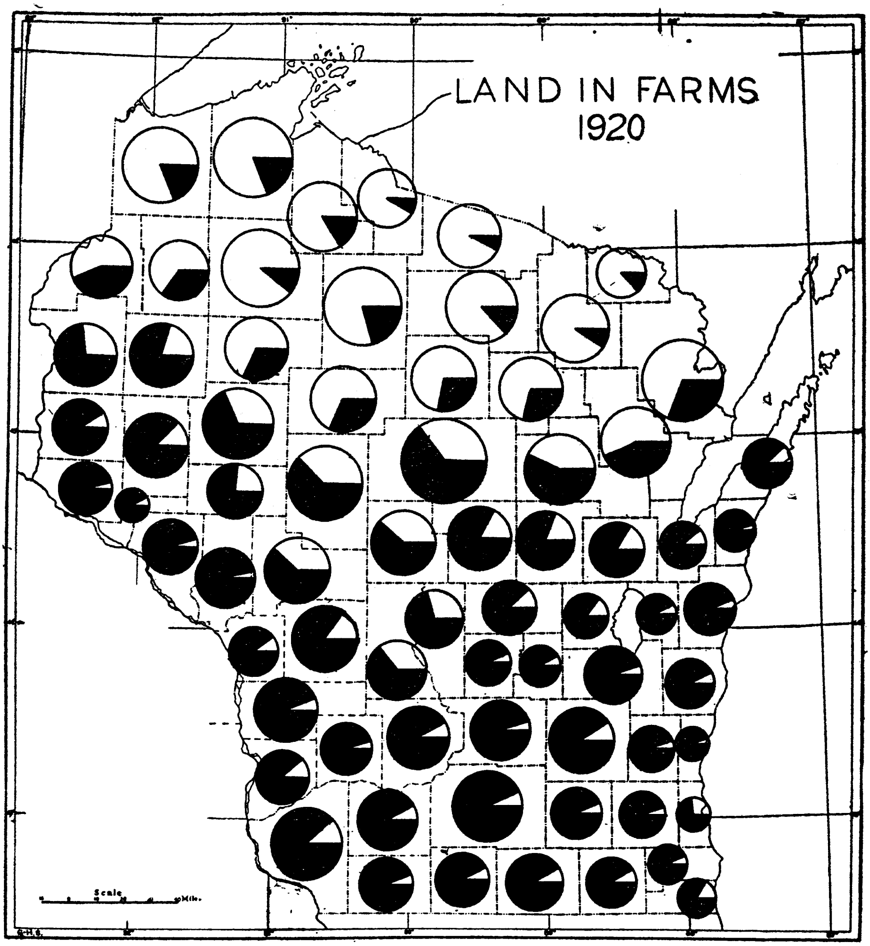

FIG. 13. Cartogram showing the land in farms in 1920. Circles are proportional to the size of the counties, and the black sectors show the percentage of the land in farms.

movement of the agricultural population. The retarding influence of the unfavorable geographical conditions was being overcome, and the desire for new agricultural land was

[39] U. S. Census. Population, 1890, p. XXVIII.

opening the north to settlement. "The census of 1890, which notes the passing of the frontier, establishes a convenient base from which to compute the pressure of that land short-

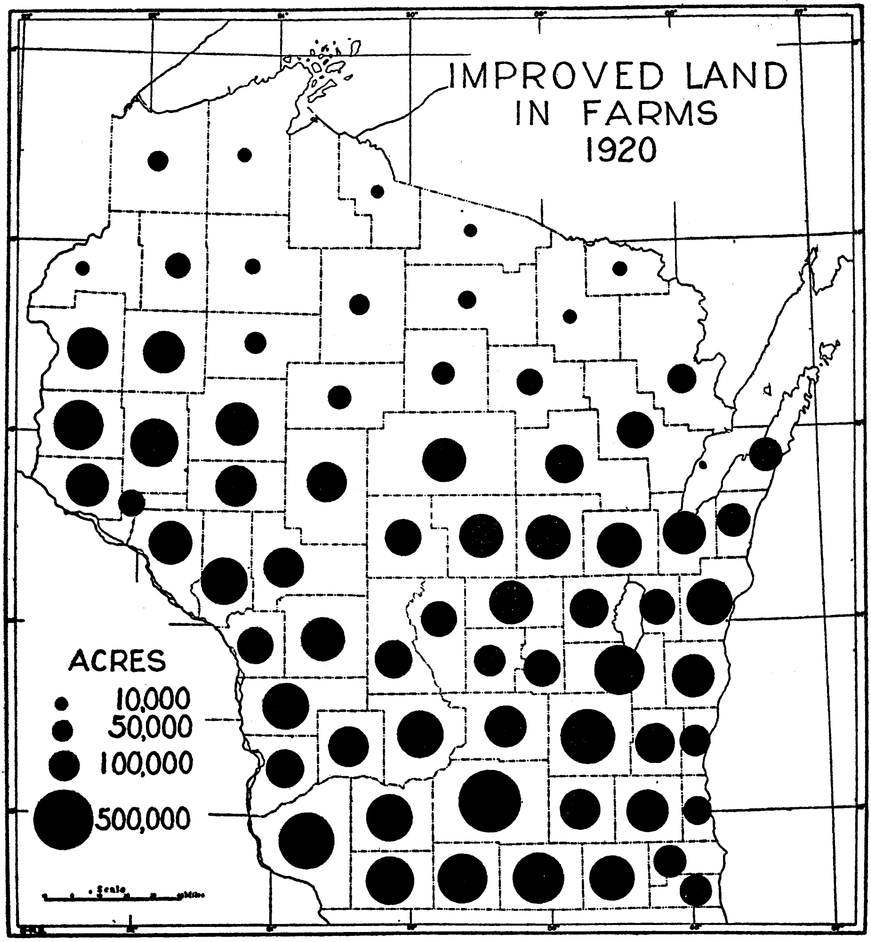

FIG. 14. Cartogram showing the general distribution of improved land in 1920.

age which gradually brought the vast and fertile areas of northern Wisconsin into requisition for general farming."[40]

The distribution of land in farms is closely related to the distribution of the rural population. (Figs. 12 and 13).

[40] Joseph Schafer. A History of Agriculture in Wisconsin, p. 139.

The amount of improved land, and the proportion of the land in farms that has been improved, are also closely related to the number and distribution of the rural inhabitants. (Fig. 14). The maps showing the land in farms and the improved land illustrate graphically the value of the land for human occupancy.

Population Growth in Wisconsin. The settlement of Wisconsin began about 1820, at a time when Pennsylvania, one of the old states, already had a population of over a million. It required fifty years, from 1820 to 1870, for Wisconsin to reach the first million, and thirty years to add the second, and probably the number will reach three million by 1930.[41]

POPULATION GROWTH IN WISCONSIN

1840	30,945	1900	2,069,042
1850	305,391	1910	2,333,860
1860	775,881	1920	2,632,067
1870	1,054,670	1922	2,708,858[42]
1880	1,315,497	1923	2,739,574[42]
1890	1,693,330	1928	2,953,000[42]

In the decade of the fifties the number added to the population of Wisconsin was 470,490, a total greater than any other ten year period in the history of the state. In the decade of the sixties only 278,789 were added, and in the seventies the declining rate of increase added but 260,827. Between 1880 and 1890 the stream of immigration contributed large numbers to Wisconsin's population, for the increase was 377,838. This was maintained in the nineties for an increase of 375,712. The two decades of the twentieth century added respectively 264,818 and 298,207 to the population. (Fig. 15).

The continued growth of population has been maintained, not only by an excess of births over deaths, but by a continued immigration from foreign countries and from the older states. In 1920 the native born Americans numbered 2,171,582 out of the total 2,632,067 people.

[41] Compare with W. O. Hotchkiss. Geography and Industries of Wisconsin. The Wisconsin Blue Book, 1925, p. 46.

[42] Estimates by the U. S. Census Bureau for July 1 of the respective years.

The westward movement that brought so many people from the northeastern quarter of the United States waned somewhat with the passing of the new lands in Wisconsin, but did not become extinct. The migration along the parallels had gained a momentum that continued in spite of the counter current that contributed so materially to the growth of cities.

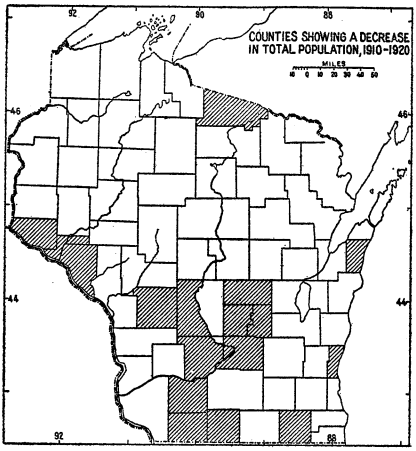

FIG. 15. Seventeen counties showed a decrease in population between 1910 and 1920. (Courtesy of the Geographical Review published by the American Geographical Society of New York).

The movement of native Americans to Wisconsin has been offset by emigration in recent years. There were living in the United States in 1920 a total of 2,460,101 Wisconsin-born people, of which 1,852,574 were still living in the state. Over 600,000 Wisconsin natives had left the state, but the loss was offset by a number, almost twice as great, that had come to Wisconsin from other states. Emigration from Wisconsin has been to the adjacent states where there is always a mutual exchange of peoples, to the older northeastern states that contributed such a large number to the early stock, and to the new western states. The exodus to the western states began about 1850 when the California gold rush stimulated the trans-Rocky Mountain 'trek' to the Pacific states. Wisconsin then had much unoccupied good land, and emigration did not take many people from the state. The passing of the easily cleared and prairie lands about 1880, and the availability of new government lands in the west caused the emigration to the trans-Mississippi states. This large number of emigrants is indicative of the passing of the frontier in Wisconsin.

Population Decrease. Population growth in Wisconsin has been attended by a readjustment in distribution that reflects the influence of geographic and economic conditions. Between 1880 and 1890 six counties showed a decrease. These were Fond du Lac, Grant, Iowa, LaFayette, Ozaukee, and Washington, all in the section that could be called older Wisconsin where a shift in population was a normal readjustment, and in certain sections the decrease was only temporary. In the last decade of the century practically every county showed an increase, only Fond du Lac continued to decline.

Between 1900 and 1910 nineteen counties declined in population, and most of these were located in western Wisconsin, which was settled between 1850 and 1890. Now a wave of emigration was carrying away the people.

The oldest part of Wisconsin was the first to be affected by emigration. Green County had its maximum population in 1870 when there were 23,611 people in the county. The maximum population for Iowa County was recorded in 1870. Similar conditions existed in LaFayette County. Emigration from the lead region set in about 1870, a few years earlier than in most parts of older Wisconsin.

In the decade from 1910 to 1920 the population of Wisconsin increased 12.8 per cent, but seventeen counties recorded decreases. This continued increase in population with the shifts from the rural to the urban communities is indicative of important readjustments in the social order. (Fig. 16).

The two sections of Wisconsin that have suffered most in the withdrawal of people are the Western Upland and the Central Lowland. Under the economic conditions then prevailing, the excess of births over deaths and continued immigration produced a pressure of population upon a land unsuited to continued economic development. As a result an emigration movement set in about 1900—locally even earlier—and has removed many people from the farms and smaller villages. The new farm lands in the west and the greater opportunities in the larger urban centers have absorbed the emigrants.

Counties such as Walworth, Ozaukee, and Kewaunee, within the industrial shadow of Milwaukee and other large cities, have experienced a decline in population. In Ozaukee County even the city of Port Washington decreased from 3,792 in 1910 to 3,010 in 1920.

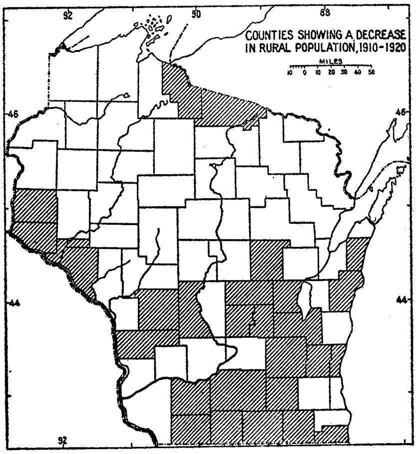

FIG. 16. Twenty-eight counties showed a decrease in rural population between 1910 and 1920. (Courtesy of the Geographical Review published by the American Geographical Society of New York).

The only county in northern Wisconsin to show a decrease was Vilas, which declined from 6,019 in 1910 to 5,649 in 1920. The very small population was materially reduced by the removal of the transient lumbermen with the passing of the pinery. In general, northern Wisconsin has been increasing in population since the first pioneers threaded their way through the forests. The decline of the lumber industry did not seriously affect the total population, for the farmers followed close upon the lumbermen. However, in Vilas County the high percentage of sand and swamp land has retarded the agricultural occupancy of the land.

Urbanization in Wisconsin. In Wisconsin as in many other states there has been a tendency toward urbanization of the population. In 1890 two thirds, or 66.8 per cent, of the people were rural and 33.2 urban, a condition differing only slightly from the average for the whole country; at that time the people of the United States were classified as 64.6 per cent rural and 35.4 urban. Ten years later, at the beginning of the twentieth century, the average for the country was 60.0 per cent rural, and 40.0 per cent urban. Similarly Wisconsin showed an increase in the proportion of urban population; the rural inhabitants made up 61.8 per cent and the urban 38.2 per cent. Wisconsin has lagged a little behind the United States in the movement of the people to the cities. In the nation 54.2 per cent were rural and 45.8 per cent urban in 1910, but in Wisconsin 57.0 per cent remained rural and 43.0 per cent urban. The census of 1920 indicates that industrial development continued to draw the people away from the rural communities to the urban centers.

This change in the division of the population does not mean that the rural population decreased. As a matter of fact the rural population of Wisconsin has steadily increased.

	Rural	Urban	Total
1890	1,131,044	562,286	1,693,330
1900	1,278,829	790,213	2,069,042
1910	1,329,540	1,004,320	2,333,860
1920	1,387,499	1,244,568	2,632,067

Because of the nature of the physical habitat, Wisconsin combines within its borders an older settled section with a frontier area in such a way that the population changes in the state approximate those of the nation. Concomitant with the expansion of agriculture in the north there has been a decrease in the rural population in the older sections. However, the net result of this change has been an increase in the rural population. From 1900 to 1920 the number of rural inhabitants increased at the rate of 5,000 per year. In the same two decades the urban population increased from 790,213 to 1,244,568 or a rate of over 21,000 per annum for the first decade and over 24,000 per annum for the latter.

The city of Milwaukee had, in 1920, 17.4 per cent of the population of the state, and if the metropolitan district beyond the city limits is included the proportion is increased to 20 per cent. (Fig. 17).

The nine cities that had over 25,000 each contained almost 29 per cent of the population. According to the classification by the 1920 census there were a total of 82 urban centers in the state, having an aggregate population of 1,244,568 or 47.3 per cent of the total. In addition there were 271,900 people living in the 375 incorporated cities and villages having less than 2,500. These are classed as

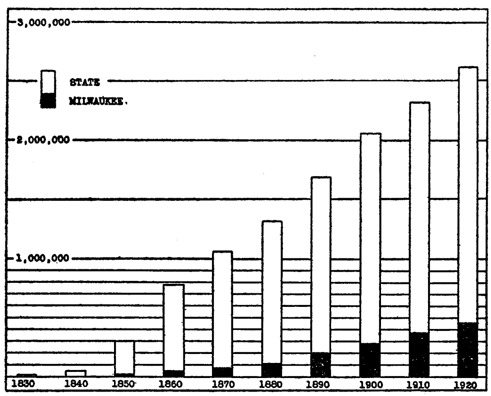

FIG. 17. The growth of population in Wisconsin has been steady in spite of sectional decreases. (Courtesy of the Geographical Review published by the American Geographical Society of New York).

rural by the Census Bureau, but they constitute 10.3 per cent of the population and when added to the 47.3 per cent swell the total to 57.6 per cent. These may be considered as strictly urban, reducing the rural element to only 42.2 per cent of the total population of the state.

The accompanying dot maps show graphically the distribution of the principal cities and villages. Lake Michigan has been of major importance in concentrating the population.

On the western boundary of Wisconsin is another waterway, once regarded as an important traffic route; but the usefulness of the Mississippi River to Wisconsin makes a poor showing when compared with the Great Lakes. Ten manufacturing cities have grown up along

the shore of Lake Michigan (including Green Bay) but only two on the Mississippi River . . .[43]

The five largest cities are Milwaukee, Racine, Kenosha, Sheboygan and Manitowoc. From the time of the settlement of eastern Wisconsin down to the present the lake shore cities have attracted a high percentage of the population. The advantages of water transportation caused the selection of urban sites along the lake. Later when the railroads came competing for the traffic, which had been almost exclusively handled by lake carriers, the growth of cities was in no way retarded. "These lake ports were the termini from which the early railroads pushed their way into the back country; consequently, they became the gateways through which the products of farm and forests proceeded to market . . ."[44]

The Fox-Winnebago Valley is second only to the Lake Michigan shore as a contributing factor in the growth of urban communities. From the time of Nicholet's visit in 1634 down to the present the Fox River Valley has been an important highway. The easy portage between the headwaters of the Fox and the Wisconsin made the Fox River one of the principal routes followed into the interior of Wisconsin during the French and English régimes. Hardly had the agricultural settlers entered the valley before there came a demand for an improved waterway to give them the full advantages of the river which nature had not made entirely navigable. The river was improved only to meet the competition of the railroads, and its usefulness as an artery of commerce declined. However, the nuclei of the present cities had been formed and other advantages within the valley contributed to urban development. The availability of water power along the Lower Fox has been of major importance in the growth of several cities. Green Bay is—and always has been—a commercial city, and owes its growth and importance to its strategic situation near the head of the bay bearing the same name. Many other cities as De Pere, Wrightstown, Kaukauna, Kimberly, Appleton,

[43] R. H. Whitbeck. The Geography and Economic Development of Southeastern Wisconsin. Wis. Geol. and Nat. Hist. Survey, Bull. No. 58, 1921, p. 31.

[44] Ibid p. 32.

Menasha and Neenah, are located on water power sites. Oshkosh on the western shore of Lake Winnebago is located at the point where the Upper Fox River enters the lake. This is a favorable location, for during the high tide of the lumber industry Oshkosh became the center of the industry that flourished along the Upper Fox and Wolfe Rivers.

Fond du Lac at the southern end of Lake Winnebago enjoys the advantage of a site favorable to commercial development.

In the lumbering days Fond du Lac derived a large advantage from the water transportation afforded by the lake. While its recent growth has but little connection with lake transportation, yet the lake is the main natural factor, though an indirect one, in the city's development. This comes about through the influence which the lake exerts upon the railway routes. The steep bluff of limestone along the eastern shore of the lake renders that side less suited to the growth of towns, and hence less attractive to railroads, and so the north-and-south railways follow the west side of the lake. Lake Winnebago is a barrier to east-and-west lines, and any such lines must bend north or south around the lake. This causes Fond du Lac to be something of a converging point for railway lines . . .[45]

In 1920 the eight cities along the Fox-Winnebago Lowland having more than 5,000 people, had a population of 132,668, or almost five and a half per cent of the total for the state.

In southern Wisconsin along the Rock and Yahara River Valley have grown up several important, though smaller, cities of Wisconsin. Madison, the capital is the largest. The others are Janesville, Beloit, Watertown, Fort Atkinson, Jefferson, Edgerton, and Stoughton.

Along the Wisconsin River a chain of cities reflects the usefulness of the river as a means of transportation and as a source of power in the lumbering and wood using industries. Northward from Portage, in order, are Wisconsin Rapids, Stevens Point, Wausau, Merrill, Tomahawk and Rhinelander.

The Chippewa with its two important cities of Eau Claire and Chippewa Falls reflects on a smaller scale the same history of urbanization as occurred along the Wisconsin River.

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[45] R. H. Whitbeck. The Geography of the Fox-Winnebago Valley. Wis. Geol. and Nat. Hist. Survey, Bull. No. 42, 1915, pp. 42–43.

La Crosse is the only city of any size on the Mississsippi River, although Prairie du Chien is an older, but smaller city, that owes its early importance to the advantage of a strategic position at the junction of the Wisconsin with the Mississippi River. The Black River, like the Chippewa and Wisconsin, drains the northern pinery, and La Crosse at its mouth flourished during the lumbering period. Its position on the Mississippi is at a point where the east-west lines of transportation, after crossing the Western Upland, reach the city by following the La Crosse River Valley.

Only two cities of any size have grown up on the Wisconsin shore of Lake Superior. These are Superior and Ashland which had in 1920 a population of 39,671 and 11,334 respectively. Superior had 40,384 in 1910, a slight decrease from the previous enumeration. Ashland decreased from 13,074 in 1900 to 11,594 in 1910, and a further decrease brought the total down to 11,334 in 1920. These two cities not only serve a local community, but the more extensive hinterland which has been the most important factor in their growth. The passing of the lumber industry has produced a slight and temporary decrease in the population, but continued agricultural expansion in northern Wisconsin will furnish a new basis for a revival in growth.

In addition to the lake shore and river sites which have been so important in the localization of the major urban communities, there are numerous situations which are ideal for smaller cities, which serve as collecting and distributing centers each for a local community. Many of these smaller cities as originally planned were expected to grow into large cities. In pioneer days these sites were purchased by speculators and held for prices above the government figure. Many of these so called 'paper towns' have become the villages and the smaller cities, except in the cases where the sites have proved to be favorable to continued population growth. The dot maps present a vivid picture of these smaller urban communities.

One important result of the urbanization in Wisconsin is shown by the movement of the center or population southward and eastward after 1900. (Fig. 18). For each of the last five census enumerations the center of population has been in Marquette County. From 1880 to 1900 it moved almost directly northward, but only half as far in the nineties as in the eighties. Settlement along the frontier had slowed down by 1890. From 1900 to 1910 the center moved eastward and slightly southward. This indicates clearly that the intensified urban growth more than balanced the northward movement. In the next decade from 1910 to 1920 the movement was slightly southeastward, illustrating Wisconsin's trend toward an industrial state.

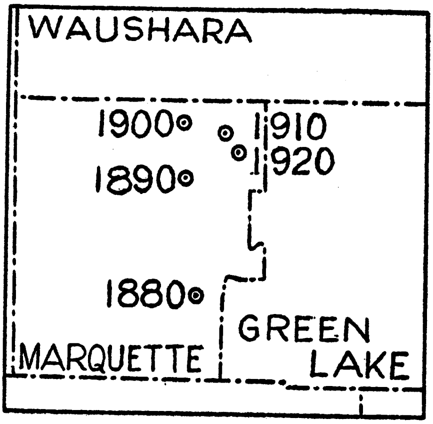

FIG. 18. A map showing the movement of the center of population since 1880. Note the eastward and southward movement since 1900. (After the Statistical Atlas of the United States, 1924).

REGIONAL READJUSTMENTS

Population distribution in Wisconsin can be effectively studied by dividing the state into regions, each of which has rather uniform environmental conditions over the entire area, or because its history deserves especial examination. (Fig. 19).

The federal census classifies all cities and villages under 2500 as rural, but in this regional study the people have been separated on the basis of the incorporation of cities and villages. All people living in incorporated districts are classed as urban, and the remainder as rural. This division, while still more or less arbitrary, separates more exactly the agricultural inhabitants from those who derive their livelihood from other occupations. It is true that the small incorporated villages have within their limits many people who are strictly agricultural. Similarly, there are

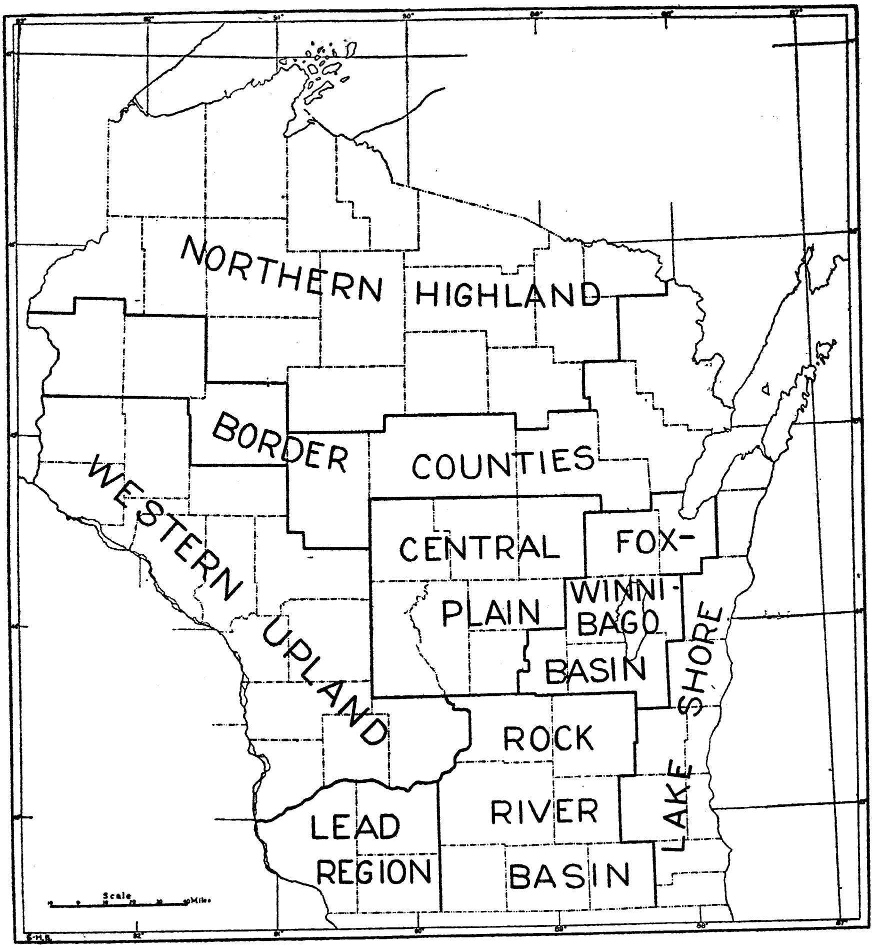

FIG. 19. There is a population sectionalism in Wisconsin. The provinces as delineated on this map permit a statistical examination of the distribution of the rural inhabitants in particular.

unincorporated hamlets with many people engaged in occupations not directly concerned with farming. These two cases mutually offset each other and probably balance any apparent inaccuracy.

The dot maps were constructed from data as reported in the United States Census, and all people living in cities and villages having a population less than 200 have been shown as rural. But there are many hamlets and larger towns having a population of more than 200—a few over 1000—which, if shown as rural, would give an inaccurate picture. Other sources have been consulted, such as local histories, Polk's gazetteers, and particularly the many annotated maps in the collections of the State Historical Society of Wisconsin. In the newer parts of northern Wisconsin the lumbering towns grew so rapidly that they attained a size much larger than many of the incorporated villages of older Wisconsin, yet they remained unincorporated, perhaps awaiting the time when the lumbering industry would remove many of the people to newer towns in the virgin forest.

The Lead Mining Region. The early settled lead mining region of Wisconsin experienced the population readjustments characteristic of mining areas. A general increase continued up until 1870 when the maximum number of inhabitants was recorded. Between 1890 and 1900 there was a slight increase from 79,033 to 82,954 for the three counties of Grant, Iowa and La Fayette. After 1900 a decrease brought the total down to 80,550 in 1920. If the number living in cities and villages is deducted from the totals as reported by the census the decrease in the rural people is more marked. In 1890 there were in these three counties 18,534 who lived in incorporated cities and villages, and the remaining 60,499 lived in the rural districts. The subsequent decennial enumerations for 1900, 1910 and 1920 reported respectively 27,685, 28,022, and 30,705 living in cities and villages. Corresponding to this increase there was a reciprocal decrease in the rural peoples. In 1900 the rural population was 55,269; by 1910 the number declined to 53,557 and in 1920 to 49,845. Part of the increase in the urban and the corresponding decrease in the rural population was due to the incorporation of six villages having a total of 1928 people. The density of the rural population in this section was only 19.2 persons per square mile in 1920 and the Agricultural Census of 1925, while not exactly comparable, indicates a further decrease to 15.5 per square mile.

The old lead mining section of Wisconsin was once the goal of many pioneers, but a century has wrought changes of far reaching importance. Like the rest of western Wisconsin the land is no longer attractive to homeseekers and a decrease in rural people is the important change to be noted. The land is only slightly less valuable than it was a hundred years ago. General farming with dairying as the specialized accompaniment has maintained the productivity of the soil. In the century that has elapsed since the first settlers penetrated the region in search of lead, the land has been continually improved. But the changing economic conditions of the country, and the use of improved labor saving farm machinery, have made it possible for fewer farmers to do the farming and at the same time increase production.

South Central Wisconsin. The counties drained by the Rock River, and adjacent sections may be called South Central Wisconsin. It is the Rock River Valley that unifies the region, though Green, Walworth and Columbia Counties are on the periphery of the area. These may be considered as transitional regions. Columbia County for example has a sandy portion along the Wisconsin River that makes it resemble very much the Central Plain, but the eastern part is more densely populated and the section is capable of supporting a larger population than the western part. Similarly Green County reflects a condition more like the three lead mining counties but Green County has never been a producer of lead. It is not only midway between the old lead mining country and the Rock River Valley but it is transitional in population conditions. Walworth, between the lake shore counties and Rock River Valley has suffered an isolation that is comparable to the handicap imposed upon Green and Columbia Counties. These three counties have shown very little growth in population since 1890. In fact Green County showed a steady decrease in total population. Dodge and Jefferson with a location similar to that of Walworth showed increases of less than the average for the state.

Dane and Rock Counties which include the three largest urban centers in south central Wisconsin have shown the greatest growth in the three decades under discussion.

Madison, the state capital, and Beloit and Janesville, industrial cities on the Rock River have absorbed the major portion of the increase in population of the two counties since 1900. Between 1900 and 1920 the total population of the seven counties increased from 285,157 to 321, 709, a gain of 36,552. The aggregate population of Beloit, Janesville and Madison increased from 42,785 to 77,955 in the same period, a gain of 35,170 or 1382 less than the total increase for the entire area.

The result of this urbanization has been a gain in population greater than the average rate of increase for the entire state between 1910 and 1920. After 1900 there has been an exodus from the farms that has reduced the strictly rural population from 166,174 to 140,102 in 1920. The land has ceased to be of fundamental importance in the growth of population.

The Lake Shore Region. The lake shore counties extend from the Illinois boundary to Door Peninsula, a distance of more than 200 miles. Washington and Waukesha Counties are included although they do not touch the lake. Because of the latitudinal extent of the region it may be subdivided into a northern and a southern section, but the place of division is more or less arbitrary.

Door and Kewaunee Counties to the north are agricultural and contain no large urban centers. Sturgeon Bay, in Door County, is the largest city and in 1920 had a population of 4553. The configuration of the peninsula limits the commercial hinterland to the extent that this eastern projection of Wisconsin has been passed-by. Farther south Manitowoc and Sheboygan Counties, because of a more favorable physical landscape and better commercial opportunities, have a much larger population. Sheboygan illustrates the growth in population, for the number in 1890 was 42,489, in 1900 it had increased to 50,345, in 1910 to 54,888 and in 1920 the total was 59,913. In contrast the last four decennial enumerations have recorded for Kewaunee successively 1890—16,153, 1900—17,212, 1910—16,784, and 1920—16,091. Kewaunee is one of the fifteen counties that showed a net decrease from 1900 to 1920, and one of the seventeen recording a decrease from 1910 to 1920.

The southern lake shore counties showed a remarkable growth from 1890 to 1920 increasing from 358,914 to 754,-354. The large total and the marked growth are due to the urbanization that has concentrated so many people in the three cities of Milwaukee, Racine and Kenosha. The growth of these cities has caused the removal of rural people from some of the adjacent counties. Ozaukee increased slowly from 1890 to 1910 but in the decade from 1910 to 1920 a decrease reduced the total below the number for 1900.

Washington and Waukesha Counties because of their inland location did not grow so rapidly as the three southern lake shore counties, but their proximity to Milwaukee is an advantage and not a handicap. This German settled section with its small farms averaging less than 100 acres has the densest rural population in the state. Urbanization has produced a decrease in the rural inhabitants, but in 1920 Washington had 41.3 persons per square mile, and Waukesha had 48.7.

Milwaukee, the smallest of the counties had the largest population in 1920. The city of Milwaukee, the metropolis of the state had in 1920 a population of 457,147, over 17 per cent of the total population of the state. If the metropolitan district is included the proportion becomes 20 per cent.

Both Racine and Kenosha Counties, like Milwaukee, have an important urban population. The city of Kenosha increased from 6,532 in 1890 to 11,606 in 1900, to 21,371 in 1910, and to 40,472 in 1920. Racine the second largest city has had a similar growth, reaching a total of 58,593 in 1920.

All of this lake shore section except the northern peninsula has maintained a large rural population. The geographical conditions are favorable to a dense agricultural population, but there can be no doubt that a social factor is of some importance, for many of the German immigrants purchased small farms from 40 to 80 acres, and from the beginning of settlement this section has been very densely peopled. (Fig. 20).

The Fox–Winnebago Basin. The six counties included in the Fox–Winnebago Basin constitute a convenient unit. Whitbeck included only Brown, Outagamie, Winnebago and Fond du Lac in his Geography of the Fox–Winnebago Valley,[46] but Green Lake and Calumet are included in this area because of their proximity and the difficulties involved by including them respectively in the Central Plain or the Lake Shore provinces.

These six counties showed a consistent gain in population from 1890 down to 1920, increasing from 203,841 to 269,121 a gain of 55,280, or over 1800 per annum. At the

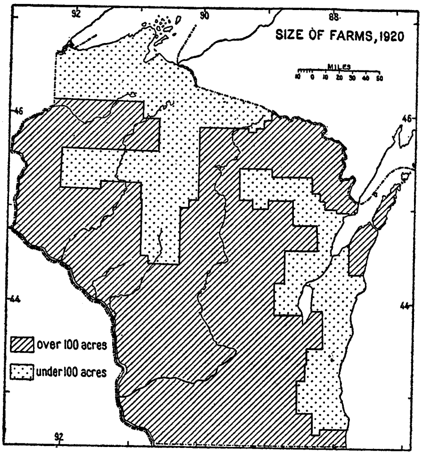

FIG. 20. The small farms of less than 100 acres are found along the German-settled Lake Shore counties and along the frontier in northern Wisconsin. (Courtesy of the Geographical Review published by the American Geographical Society of New York).

beginning of the period the rural exceeded the urban population, but by 1920 the urban inhabitants had been increased to almost two-thirds of the total. In 1920 the eight principal cities had almost half of the population.

Accompanying the urbanization there has been a reciprocal decrease not only in the proportion of rural population, but in the aggregate. From 1890 to 1920 this section has lost approximately 360 persons per annum from the farms. Like all of older Wisconsin, the passing of the frontier has brought in its wake a depopulating of the older agricultural sections. Still the average density of the rural population remains over 30 per square mile, less than in Washington

[46] Wis. Geol. and Nat. Hist. Survey. Bull. No. 42.

County and greater than in the more rugged Western Upland.

The Central Plain. The seven counties of Adams, Juneau, Marquette, Portage, Waupaca, Waushara and Wood are not entirely within the sandy Central Plain; Adams, Marquette and Waushara belong to the sand country and may be chosen to illustrate the influence of the land conditions upon density of population. Since 1900 the population of the seven counties has increased slowly, reaching a total of 158,143 in 1920 or about 32 persons per square mile, or only 20 rural inhabitants per square mile. The total area of these seven counties is almost 5000 square miles. The reduction in rural population was at the rate of 400 per year for the two decades after 1900, which means that each year every 12 square miles of area lost one rural inhabitant.

A comparison between Adams and Waushara illustrates the influence of glaciation on the habitat. Adams County is in the Driftless Area and Waushara in the glaciated region. In 1920 the population of Adams County was 9,287 or 13.6 persons per square mile. If the people living in the three incorporated villages are deducted the density was only 11.3 per square mile. Waushara,—like Adams in all essentials except that it was glaciated,—had in 1920 a population of 16,712 or 25.9 persons per square mile, or if only the strictly rural population is considered the density was almost 20 per square mile. It is a significant conclusion that the Central Plain was benefitted by glaciation. Every square mile of the glaciated plain supported at least one more family than did the driftless portion of the plain.

Western Wisconsin. The fourteen counties of western Wisconsin north of the Lower Wisconsin River showed an almost static condition of the total population after 1900. From 1890 to 1900 the population increased from 307,313 to 341,984, a gain of 11 per cent as compared with the 22.2 per cent for the state. Between 1900 and 1910 there was a slight decrease, but by 1920 an increase brought the aggregate up to 347,274, the maximum attained in any enumeration.

An examination of the cities and villages reveals quite a different condition. In 1890 the urban population numbered 93,867, almost a third of the total. The steady increase in the urban population has materially reduced the rural element. In 1920 the urban element made up 41 per cent of the total. This change is due not only to urbanization characteristic of older Wisconsin, but emigration has played an important part, particularly between 1900 and 1910.

Vernon County represents a fair cross section of the rugged and unglaciated portion of the Western Upland. The region is maturely dissected, but there are preserved upon the upland broad areas that were originally prairie. The slopes are too steep for utilization other than for pasture and woodland. From 1890 to 1920 the increase in the total population was only 4,141. In the same period the incorporated cities and villages grew from 2007 to 7614, a gain of 5607; the increase in the urban group not only absorbed the total gain of the county in the thirty years but effected a decrease in the rural population. The emigration from the farms averaged almost 49 people per year for the 30 year period from 1890 to 1920.

In Vernon County as in most of the Western Upland the momentum of settlement imposed upon the land too many people who looked to it as a source of livelihood. The decline in the rural population is a normal readjustment, and a continued decrease would help to relieve the agricultural situation.

Northern Wisconsin. The newer northern part of Wisconsin contained after 1880 much land that was still to witness the coming of the agricultural pioneers. The lumbering industry was at the height of its activity preparing the way for the farmers who were cautiously penetrating the wilderness and taking up the new lands.

The sixteen modern counties constitute a frontier section of the state where the growth of population repeats the conditions of a half century ago when southern Wisconsin was on the frontier. The growth in population is accounted for by an increase in both the rural and urban elements, with the rural increase exceeding the urban.

Adjacent to these sixteen counties of northern Wisconsin are eight others that occupy a crescent shaped area near the southern boundary of the Northern Highland. The total area of these eight counties is somewhat smaller than the more northern counties but the population conditions are strikingly different. In 1880 the northern counties had only 11,710 people as compared with the 89,517 in the border counties. At the subsequent decennial enumerations the border counties failed to maintain this large margin in population. By 1900 the border counties had a total of 222,790 and the northern counties 161,698, and two decades later (1920) the border counties had 293,452 and the northern, 260,743. The two areas showed a growth of both rural and urban population. Ashland and Superior, the two largest cities in northern Wisconsin and serving a larger hinterland than the adjacent tributary area, made up a large proportion of the population. These two lake shore cities contained half of the urban population in 1890.

The census enumerations for 1900, 1910 and 1920 show that both the urban and the rural populations grew steadily until there were 260,743 in the northern section in 1920. Of this number 113,117 were urban, with the combined population of Superior, 39,671, and Ashland, 11,334, making up almost half of the total, a condition that obtained 40 years previously. In 1900 the urban population in the border and the northern sections was approximately equal, but by 1920 the people living in incorporated cities and villages numbered 113,117 in the northern counties and 102,511 in the border counties. This leaves a larger rural population in the smaller border section where agricultural conditions are better.

The value of the cut-over land in northern Wisconsin has been frequently over-stated. The land companies are anxious to dispose of the land to settlers, and exaggeration of the real value has caused much hardship. However, there have been made more reliable statements that have served to make some of the settlers more cautious in the selection of land. In 1896 Henry[47] estimated that one to one and a half million acres have swamp or humus soils and, therefore, unsuited to agriculture. Interspersed between the patches of wet and otherwise inferior land are extensive areas of valuable land which await the coming of far-

[47] W. A. Henry. A Handbook for the Homeseeker, p. 6.

mers who are willing to devote a lifetime to the removal of the forest.

In recent years a more conservative estimate of the northern land deserves a wider circulation than it has received. Packer and Gunderson estimate that "forty per cent of our unoccupied cut-over land is unsuited to farming . . ."[48] One of the tragedies of agricultural settlement on the poor land is a realization after a few years of the futility of labor. A farmer and his family may have come hundreds of miles to a new home which has been described to them as offering advantages and opportunities approaching their greatest ambitions. When all of their resources are invested in the land they cannot afford to leave nor can they see a prosperous future. In a few years it becomes home to them. Though they remain poor struggling farmers, their sentimental attachment to the soil is too firm to be broken by changing economic conditions. They find consolation in the hope that increased land values will repay them in some measure for their years of toil.

In spite of the handicaps imposed by a more or less hostile environment the better farm lands of the northern part of the state have been brought under cultivation. Steadily the agricultural frontier encroaches upon the cut-over land, and the increase in improved land is most marked along the crescent margin of the northern highland, the area already referred to as the border counties. The settlement along the periphery of the northern section has been delayed because the Central Plain acted as a deterrent.

It has been said that if all the settlers who in the past 50 years have been sold land in the sandy central plain of Wisconsin and have failed in consequence had been taken a few counties farther north and sold some of the good silt loam lands, most of the good land in northern Wisconsin would now be in farms. In Wisconsin in particular the crescent-shaped . . . plain stretching all the way from Burnett County in the northwest to Marinette County in the northeast, and more than two counties wide in the center, has served as a very effective barrier against development north of it.[49]

[48] B. G. Packer and Oscar Gunderson. Preliminary Biennial Report of the Wisconsin Department of Agriculture, Immigration Division, Madison, 1923–1924, p. 45.

[49] J. D. Black and L. C. Gray, Land Settlement and Colonization in the Great Lakes States, U. S. Department of Agriculture. Dept. Bull. No. 1295, Washington, 1925, p. 12.

The settlement of the more northern part of Wisconsin has been in progress for half a century. The agricultural expansion began about 1880 yet only about six per cent of the area yields harvested crops. "At this rate it would take over 750 years to complete the conquest of the northern woodland."[50] It is obvious that the settlement of northern Wisconsin in recent years resembles only slightly the frenzied western migration that began the settlement of older Wisconsin a century ago.

CONCLUSION

In the settlement of Wisconsin there has developed a sectionalism in the distribution of the population which reflects the physical conditions of the landscape, the soil, the climate, as well as the social elements. The changes wrought in almost three centuries of history present a sequence of cultural stages. The type of people and the stage of their civilization determine the use that they will make of their regional habitat and the number that a given area may support. " . . . each mode of life has its own space requirements which are larger for the hunter or shepherd than for the agriculturist . . ."[51]

During the period of exploration, Wisconsin supported a few hundred whites and a few thousand aborigines who hunted, almost to extermination, the fur-bearing animals. The effects of the glacial climate of a past geological period persist into the present, creating an ideal habitat for the fur-bearing animals. For more than a century a few thousand people in a primitive stage of civilization lived in Wisconsin and won a livelihood from the fur industry. Only when the agriculturalists with their higher cultural aims came into possession of the land was the intrinsic value of the soil fully realized. Gradually the development of commerce, manufacturing and service occupations has produced readjustments in population distribution in keeping with the cultural progress of mankind.

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[50] B. H. Hibbard, John Swenehart, W. A. Hartman and B. W. Allin, Tax Delinquency in Northern Wisconsin. Agricultural Experiment Station. University of Wisconsin, June 1928, p. 9.

[51] Paul Vidal de la Blache. Principles of Human Geography, p. 155.

Beneath the film of population unevenly spread across the regional landscape of Wisconsin the effects of soil, drainage, relief, and climate persist as the eternal economic bases of the relation of man to his habitat. But it must be remembered that man, because of his intelligence, can exercise judgment in his relations to his physical environment. He is not as specialized as the lower animals, " . . . for his mentality and communal co-operation are such that he alone of the animal kingdom can produce artificial harmony between himself and the environmental complex where disharmonies actually occur."[52] Furthermore, social inheritances may impel man to act in certain ways while his neighbor, because of a different inheritance, behaves differently. In spite of the influence of social conditions "It is more than probable that soil and climate influence the distribution of men on the surface of the globe, and facilitate or hinder their concentration or dispersion. It is for demography to undertake the study of both that concentration and that dispersion."[53] In Wisconsin the settlement and the distribution of the inhabitants reflect in a variety of ways the significance of the frontier and the persistence of the regional geography in the development of a population sectionalism.

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[52] Raymond Swann Lull. The Ways of Life, p. 244.
[53] Lucien Febvre. A Geographical Introduction to History, p. 34.

GLACIAL GEOLOGY OF PART OF VILAS COUNTY, WISCONSIN[1]

F. T. THWAITES

INTRODUCTION

This study of the glacial geology of part of Vilas County, Wisconsin, was begun on September 23 and was terminated on October 30, 1927. The area surveyed is shown on the accompanying map (fig. 1). It comprises Townships 40 to 44, inclusive, and all of Ranges V, VI, VII and part of Range VIII East. On account of the diagonal location of the state boundary, this area includes only about fourteen and a half townships, or approximately 522 square miles. Many lakes and lakelets are situated within the area and this study of the glacial geology of the region was carried out in connection with an extended physical, chemical and biological investigation of these lakes. Only a few of the larger lakes are shown in figure 1.

A study of glacial geology is primarily a study of topography and only secondarily a study of material. Extensive views of the surrounding territory are, therefore, of chief importance, though exposures can by no means be neglected. Since most of the region is covered with second growth timber, this survey was made in the autumn after most of the leaves had fallen from the trees; even after the leaves are almost gone, the density of the brush in many places severely limits the field of observation. Work was done preferably along roads and railroads, especially where extensive views of the surrounding territory were available. About 16 square miles per day were covered in the survey.

All of the maps of the region are extremely inaccurate owing to inaccuracies in the original Government Survey. Thus much more time must be spent at times in finding exact locations than in making the observations on the geol-

[1] Published by permission of the State Geologist.

ogy. Resurveys are being made in some parts of the area and eventually more accurate maps will be available.

Acknowledgments. Aid was received from J. J. McDonald, State Cruiser at Trout Lake; Clarence Buck, Clerk

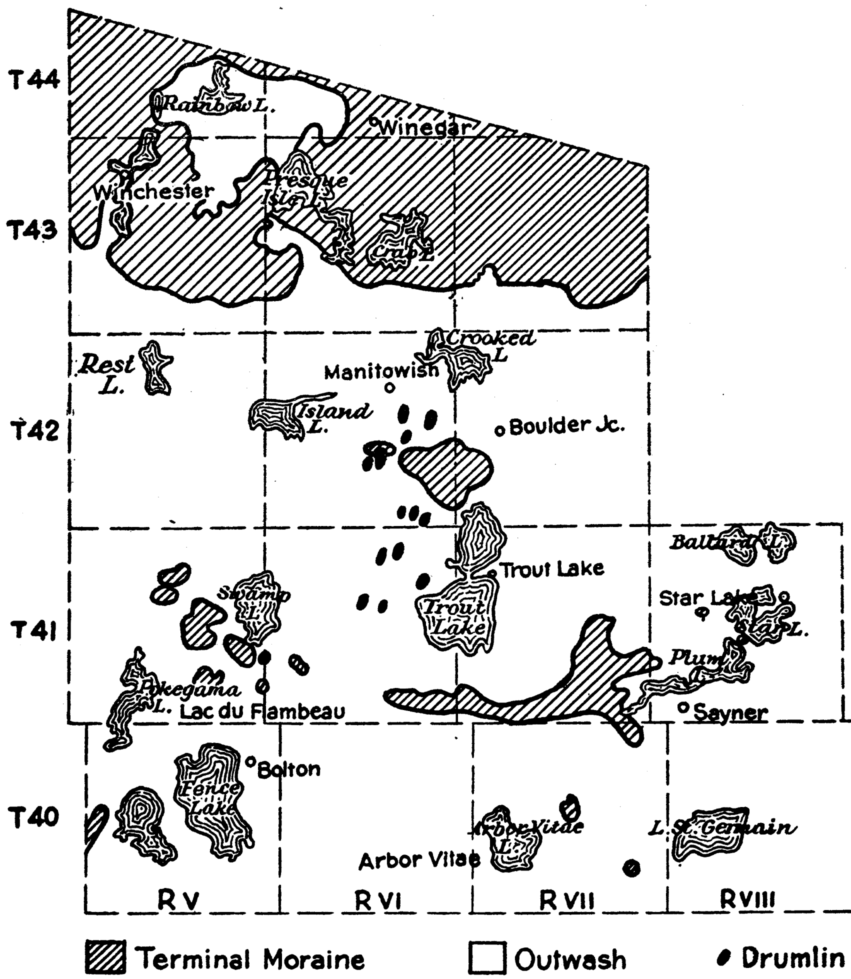

FIG. 1.

of the town of Winchester; and William F. Kunschki, Assessor of the town of Winegar. Profiles of the principal railways were furnished by W. L. Towne, Chief Engineer of the Chicago and Northwestern Railway, and C. F. Loweth, Chief Engineer of the Chicago, Milwaukee, St. Paul and Pacific Railroad.

Elevations. From the railroad profiles as a base, aneroid readings were extended over the entire area, with particular attention to the levels of the lakes. Great care was used in making these readings and it is believed that the great majority of the results are correct to the nearest 10 feet. Table 1 shows the results of these observations.

TABLE 1. *Elevations of lakes in Vilas County, indicated in feet above sea level.*

Lake	Town No.	Range E.	Elevation
Alder	42	V	1600
Arbor Vitae	40	VII	1605
Armour	43	VI	1645
Ballard	41	VIII	1670
Bass	42	VI	1635
Bass	41	V	1615
Bear	41	VII	1645
Big	42	VI	1600
Birch	43	V	1635
Boulder	42	VII	1625
Carlton	43	VI	1650
Clear	42	V	1590
Clear Crooked	42	VII	1630
Crab	43	VI	1655
Crawling Stone	40	V	1570
Crooked	41	V	1620
Dam	42	V	1580
Day	41	VI	1625
Edith	42	VI	1630
Fence	40	V	1590
Fishtrap	42	VII	1640
Flambeau	40	V	1570
Found	40	VIII	1630
Grassy	42	VII	1650
Gresham (Upper)	41	VI	1605
Gunlock	40	V	1575
Halfway	41	VI	1600
Harris	44	V	1665
High	42	VII	1640
Horsehead	43	VI	1640
Irving	41	VIII	1670
Island	42	VII	1590
Jag	42	VI	1625
Katinka	43	VI	1655
Little Arbor Vitae	40	VII	1605
Little St. Germaine	40	VIII	1610

TABLE 1. *Elevations of lakes in Vilas County, indicated in feet above sea level.*—(Continued)

Lake	Town No.	Range E.	Elevation
Lone Tree	41	VIII	1680
Long	41	VII	1650
Lost	40	VIII	1620
Lynx	43	VII	1700
Manitowish	42	V	1590
Mann	41	VII	1625
Muskellunge	41	VII	1635
Oswego	42	VII	1655
Oxbow	43	VII	1690
Papoose	43	VI	1640
Plum	41	VIII	1635
Plummer	40	VI	1625
Pokegama	41	V	1570
Presque Isle	43	VI	1635
Rest	42	V	1590
Rock	44	V	1640
Rock	41	VII	1630
Ross	40	VII	1637
Rozen	40	VII	1615
Sand	41	V	1615
Shishebogama	40	V	1565
Star	41	VIII	1670
Stearns	41	VI	1610
St. Germaine	40	VIII	1593
Sturgeon	42	V	1580
Sugarbush	41	V	1605
Trout	41	VII	1617
Twin	40	V	1595
White Birch	41	VIII	1665
Whitefish	40	V	1585
White Sand	42	VII	1636
Wishou	40	VI	1620
Wolf	43	VII	1640

BED ROCKS

Outcrops. Vilas County is nearly devoid of outcrops, only three are known in the region surveyed. Two ledges in secs. 34 and 35, T. 43, R. 7 E., northwest of High Lake, were visited by the writer; the rock is a coarse gray and pink granite with pegmatite dikes. The exposures are in a pitted outwash plain although erosion by glacial streams doubtless had a part in uncovering the rock. Allen and Barrett[1] report a ledge of gneiss between Spider and Island lakes which was not visited by the writer.

Drill holes. During the late panic over iron ore reserves the area was explored by Allen and Barrett for the F. I. Carpenter syndicate. The general results of this work have been published but not the detailed logs of the numerous drill holes. No exploration is now going on and it is reported that some of the lands which were purchased have since been sold. The drill holes were for the most part on magnetic lines and found granite, quartzite, slate, iron formation, and various types of schist. Few of the published logs give the depth of drift, but these data were secured from the files of C. K. Leith. In this area it varies from 129 to 234 feet. The relief of the bed rock surface is, therefore, not great. The explorers named some of the concealed ranges of much altered iron formation; that which passes through the village of Winegar is the Turtle Range and the much more irregular magnetic belt south of it they called the Manitowish Range. The latter seems to be underlain solely by schist and gneiss. The prevailing strike of folds and schistosity is about N. 70° E.

Inferences from drift. Virtually no unassorted glacial drift is found in Vilas County south of the latitude of Crab Lake. This fact renders conclusions as to the character of the bed rock rather difficult to arrive at since a large part of the material of the drift may have been transported considerable distances by water in addition to its journey by ice. The transportation by water also removed most of the fine material derived from slates, shales, and soft iron formation. The pebble and bowlder counts show that pink and gray granites and pegmatites, many of which are probably local, predominate. Basalt, both dense and amygdaloidal, diabase, rhyolite, red sandstone, and red shale, all obviously derived from the Keweenawan rocks to the north, make up a large part of the pebbles. There are very few fragments of quartzite and iron formation. The fine material is in large part quartz sand which in the till is mingled with a

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[1] Allen, R. C., and Barrett, L. P., Contributions to the pre-Cambrian geology of northern Michigan and Wisconsin: Michigan Geol. and Biol. Survey Pub. 18, pp. 65–130, 1915.

considerable amount of red clay probably derived from the red Keweenawan and Huronian rocks to the north. It is not at all probable from these data that any large areas of Huronian rocks exist in Vilas County. The drilling showed that such as are present are much altered by intrusive granits as well as by regional metamorphism. It is highly doubtful that any areas of merchantable iron ore can exist in the area surveyed. The writer is convinced that the bulk of the bed rock is granite and gneiss. The immense amount of sand came from the Keweenawan or Cambrian sandstones to the north.

TOPOGRAPHY

Elevation. The highest known point in the area surveyed is the hill on which Muskellunge Fire Tower is situated (sec. 34, T. 41, R. 7 E.) which reaches an elevation estimated at 1825 feet above sea level. The lowest measured point is Shishebogama Lake in T. 40, R. 5 E. at 1565 feet. The general surface of the country declines from about 1700 feet at the northeast to about 1600 feet in the southwest; 1650 feet is a general average for the country surveyed.

Relief. Vilas County is a region of relatively low relief (fig. 2). Local differences of elevation of much over 50 feet are not at all common although on the other hand extensive flats are rare. The roughest portion of the area is at the north. Here the hills are very irregular both in outline and in summit elevation and local differences of 75 feet are common. Interspersed among these hills are many enclosed basins, a large number of which contain lakes and ponds. This is by all odds the most picturesque portion of the area. Farther south the landscape is a broken plain which offers much more monotonous scenery. Locally small hills and ridges rise above the general level. The lakes and swamps are set in partially or wholly enclosed depressions which range from a few feet to 50 feet in depth. Most of the lakes are shallow and small; Trout Lake is the largest and deepest. The total depth of its depression is about 115 feet.[2]

[2] Juday, C., The inland lakes of Wisconsin: Wisconsin Geol. and Nat. Hist. Survey Bull. 27, p. 129, 1914.

DRIFT DEPOSITS

Vilas County is remarkable for the monotony of the glacial geology, that is, for the large size of the individual areas of the same origin (fig. 1). It is also noted for the simplicity of the geology and the lack of features with a complex glacial history. In spite of this fact, the geologist is compelled by the lack of extended views to traverse the region rather fully lest some relatively small feature escape him and thus make his rendering of the story incomplete. An effort was made to visit every section unless obviously all swamp or all plain.

Types of deposits. The drift deposits of the area surveyed can be divided into (a) outwash, (b) terminal (recessional) moraines, (c) drumlins, (d) ground moraine, and (e) eskers. Of these, the first covers by far the largest portion of the region and the second forms the most conspicuous topographic features and the most striking country. The other features cover only an inconsequential percentage of the region.

Outwash. The most widespread and characteristic drift deposit of the lake region of Vilas County is outwash which contains numerous kettles, that is *pitted outwash.*[3] The material is nearly all horizontally bedded sand which for the most part contains scattered pebbles and a few bowlders. Some small cross bedding is generally present. Fairly well sorted, locally very bowldery gravels are present in some places. The topography varies from level as southwest of Boulder Junction to so much pitted that no upland is left between the kettles; this last type is well shown in the vicinity of Witches Lake west of Sayner. In many places the uplands between the kettles are small but when the geologist stands on one he can see at once that the other summits form the remnants of a once continuous plain. Many of the kettles extend below the water table and therefore contain marshes or lakes. The majority of the lakes of Vilas County are of this origin. They have low sandy and in most cases uninteresting shores. In the very much pitted areas the resemblance to terminal moraine is striking, es-

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[3] Thwaites, F. T., The origin and significance of pitted outwash: Jour. Geology vol. 34, pp. 308–319, 1926.

pecially where bowlders are present. Discrimination is not difficult, for in such cases neither the coarse gravel nor clayey till of terminal moraines is present. In many places the deposits are terraced into two or more distinct levels, all pitted (fig. 2). It proved impracticable to map the distribution of such terraces over any extended area because of the lack of accurate topographic maps.

Terminal moraine. Terminal moraine topography consists of knobs with intervening sags; there is neither a level upland nor an equality of summit levels. The terminal moraines form elevations above the adjacent outwash areas. The material of the moraines consists of glacial till, ill-assorted gravel, sand, and red clay. Bowlders are conspicuous in most terminal moraine areas. Where the land is still covered with virgin timber with its accompanying vegetable mould and fallen leaves they are not easily seen. Three distinct moraines, and traces of a fourth have been discriminated as shown on the accompanying map (fig. 1). Of these only the northernmost, the Winegar moraine, contains a large amount of till. This till is red in color and contains pockets of bowldery sand and red clay. Locally the surface is covered with a few feet of pebbly sand. The red till is bleached to a yellowish gray to depths of several feet from the surface. Lakes are abundant in the kettles and some of the finest bodies of water in the area, such as Crab Lake, are found in this moraine. The other moraines, the Boulder and the Muskellunge, are, so far as could be discovered, composed wholly of assorted material. They can be distinguished from the adjacent outwash by the great abundance of bowlders, the coarseness and ill-assortment of the gravels, and by their topographic form of ridges transverse to the direction of glacial movement. Both of these moraines are discontinuous and are represented in some places by isolated knolls of bowldery composition which rise from the adjacent outwash plains.

Drumlins. Drumlins were not known in this portion of Wisconsin previous to the present survey but had been found in Iron and Gogebic counties, Michigan, by Leverett[4] so

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[4] Leverett, Frank, Surface geology and agricultural conditions of Michigan: Michigan Geol. and Biol. Survey Pub. 25, Plate I, 1917.

that their discovery should excite no surprise. Mapping of drumlins is exceedingly difficult in forested country and it is possible that more drumlins might be recognized were conditions more favorable for observation. It is probable that many other drumlins lie buried beneath the outwash plains from which only the highest project.

The mapped drumlins lie west and northwest of Trout Lake with a single outlying specimen just south of Highway 70 in T. 40, R. 5 E. Of these, the latter may very well be a portion of a group most of which lies south of the area mapped, for drumlins rarely occur alone. It also seems possible that the stony ridge in the so-called Game Farm east of Trout Lake may be a drumlin. The recognized drumlins range from less than a quarter of a mile in length to over three quarters of a mile. The width varies from a third to a quarter of the length. The maximum known height is about 100 feet. Some of the most accessible and perfect drumlins are situated west of Boulder Junction near the Manitowish Fire Tower. All the observed drumlins have a trend of 30° to 40° west of south.

Ground moraines. No true ground moraine, that is thin, rolling drift through which the older rock topography shows, is present in the area surveyed. An area southeast of Big Papoose Lake in T. 43, R. 6 E. is bowldery, gently rolling, and is apparently underlain by till. It was mapped as ground moraine because of the low relief, but its origin is doubtless associated with the drainage from the ice front at this point which eroded and leveled some of the border of the Winegar moraine.

Eskers. Eskers are the beds of glacial streams which were confined by walls of ice. They consist of relatively low discontinuous ridges of coarse, ill-assorted gravel. The discovery of eskers in a forested region is a matter of chance. Many eskers are probably buried under the outwash and in a few places the ice blocks which formed the kettles served to protect a portion of an esker from such cover. Discrimination of esker remnants from accidental ridges between pits is a matter of examining the material. Unless cuts are present, such examination is very difficult. One of the best eskers which was discovered is that crossed by the old railway grade in sec. 10, T. 42, R. 6 E. It is possible that the ridge of coarse gravel west of Crawling Stone Lake is really a gigantic esker and not a moraine as mapped.

Glacial History

The glacial history of the region surveyed is, so far as the evidence there observed goes, relatively simple. It tells only of the last, or Wisconsin, glaciation which in this region ended in a relatively rapid retreat of the ice front interrupted by three or four halts. The times of relatively stationary margin resulted in the formation of successive moraines. The comparative durations of the halts may be estimated from the size of the respective moraines; this criterion shows that the formation of the most northerly or Winegar moraine took longest. During each halt floods of water from the melting ice buried the country just vacated beneath their load of sediment.

Direction of ice movement. The direction in which the glacier moved in Vilas County is shown by (a) the direction of the long axes of the drumlins and eskers, (b) the trend of the terminal moraines, (c) marks on bed rock, and (d) the direction of the long axes of many of the lakes. All of these indicate a motion toward the southwest (about S. 35° W.). The single observed groove on a ledge bears S. 50° W.

Formation of ground moraine and drumlins. When the ice margin of the Wisconsin glacier stood at the outermost moraine in Lincoln County, doubtless some drift, possibly including some of the drumlins, was deposited. It is possible, however, that these particular drumlins were not formed until the ice edge had melted back some distance, but they were undoubtedly in their present form before the border reached the area surveyed, as drumlins are rarely found within ten miles of the farthest extent of an ice sheet. A considerable portion of the unassorted drift or ground moraine was undoubtedly formed during the last melting of the ice.

First halt of ice margin. The first record of a halt of the ice margin within the area surveyed consists in some scattered moranic knolls in T. 40, R. 5 E. All these are small and of such character that some might equally well be simply large eskers or possibly in part imperfect drumlins. If any definite moraine was formed, it is now almost wholly buried in outwash.

Muskellunge Moraine. The halt of the ice margin which allowed the deposition of the Muskellunge Moraine followed upon such rapid melting of the glacier that retirement from the area to the southwest was not complete. In hollows, valleys, and depressions between drumlins masses of stagnant ice from a few feet to two or three miles in width survived just as isolated bodies of troops are left behind during the retreat of a defeated army. Protected only by a mantle of melted-out drift accumulated from their own burden, these would soon have succumbed to the sun's rays; but while the ice margin was at the Muskellunge Moraine, vast quantities of water flowed from the glacier and buried these isolated ice blocks in sand and gravel with scattered bowlders carried by ice bergs. This extra cover prolonged the life of many of the glacial remnants. The material of the moraine itself was also worked over by water. As originally deposited the moraine rose above the outwash plain to the south in only a few places, notably at the hill where the Muskellunge Fire Tower now stands. Near the moraine this plain had an elevation of about 1700 feet above sea level. It sloped gently toward the south and southwest. The outwash at Lac du Flambeau Station is unusually bowldery and coarse. Such stony layers are doubtless present elsewhere and await discovery by deep digging.

Boulder Moraine. What caused the alternating rapid retreats and periods of relative stability of the ice margin is not known. Certainly in Vilas County it was not due to melting back to positions where the glacial front was protected by hills although it is true that as a moraine accumulated, it tended to prolong the halt by protecting the ice from the sun. More likely changes either in local climate or in nourishment of the ice to the north were the cause. The Boulder Moraine marks a retreat of about 8 miles and the deposition of an outwash plain which buried blocks of ice up to about four miles long and at least 150 feet thick. Such large blocks may have projected above the sand plain. The deposits buried much of the formerly deposited terminal moraine as well as all the intervening ground moraine and many drumlins. The elongations of many of the ice blocks in a northeast-southwest direction is doubtless explained by their location in low tracts between drumlin uplands, for drumlins occur in groups arranged parallel to the direction of ice movement. Moreover, it is possible that preglacial or interglacial valleys trended toward the southwest. The streams from the new ice front found lower courses than had prevailed when the plain south of the Muskellunge Moraine was completed. In part this was due to lower outlets freed by the recession of the main body of the ice and in part to melting of buried ice blocks in the outwash to the south which opened new drainage lines. The result was to cut away a large portion of the high level plain south of the Muskellunge Moraine before all of the buried ice masses had melted, for there are many kettles in the later drainage lines. Large portions of the older moraine were also eroded away or buried under outwash. When the ice blocks melted, the bowlders they contained were deposited in the resulting kettles or pits.

Winegar Moraine. The formation of the Boulder Moraine was followed by a retreat of about five miles after which a prolonged halt of the border caused the deposition of the big Winegar Moraine. That this moraine is one of recession and not of readvance is demonstrated by the gradation of the moraine into the pitted outwash south of it. Had the ice front retired long enough to permit melting of the buried ice blocks, unpitted outwash would have been deposited along large portions of the border of the moraine. No such deposits are present. The Winegar Moraine contains less water-sorted material than do the other moraines of the area, but there are many kames and several large patches of pitted outwash, probably not all mapped, within the moraine proper. Some of these outwash plains had drainage outlets over blocks of ice which have since melted to form lake basins. Kettles formed when the isolated ice masses which were buried in the till melted; into those kettles which formed before the surrounding moraine was clad

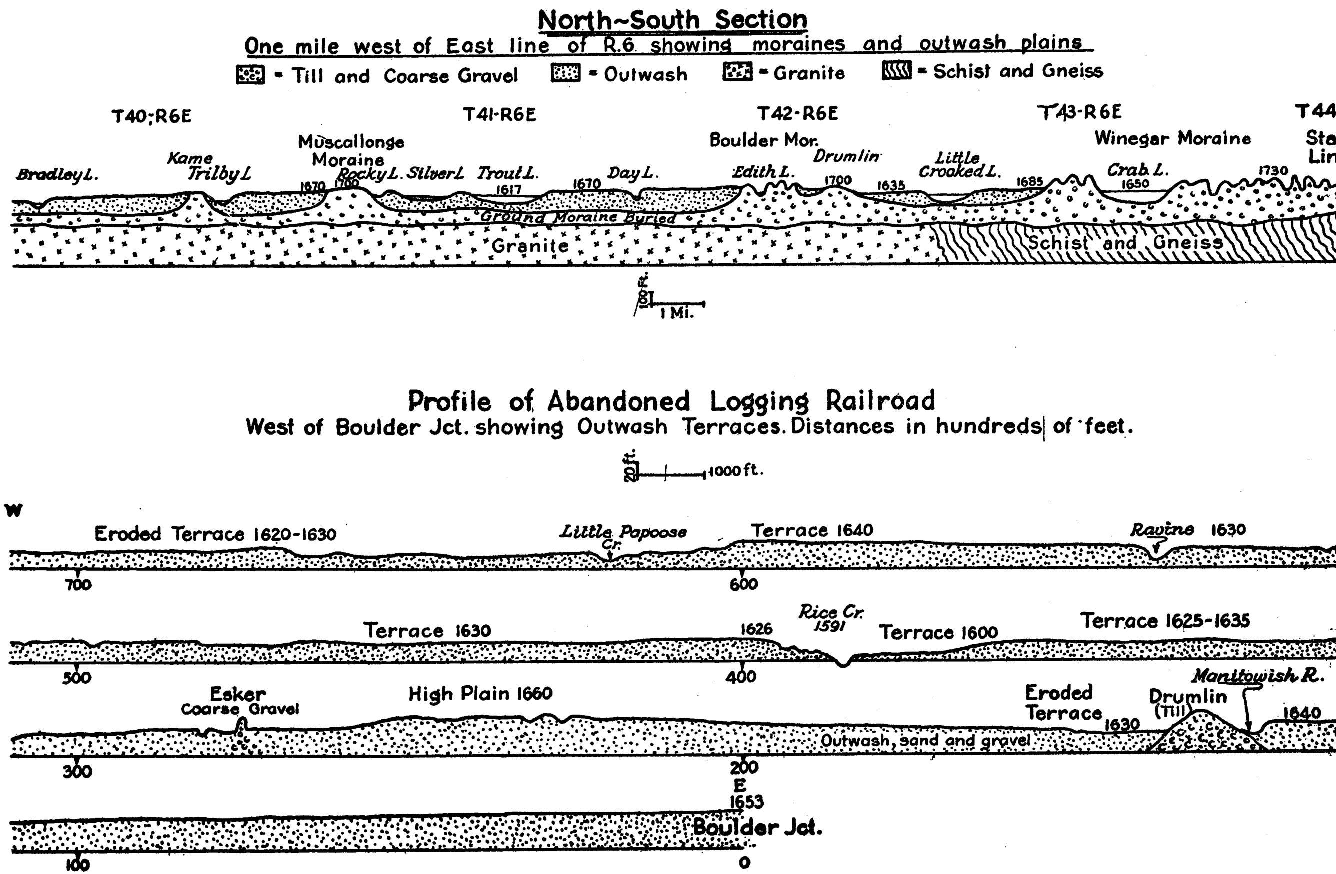
North~South Section
One mile west of East line of R.6 showing moraines and outwash plains
= Till and Coarse Gravel
= Outwash
= Granite
= Schist and Gneiss
T40;R6E
T41-R6E
T42-R6E
T43-R6E
T44-6E
Bradley L.
Kame
Trilby L
Muscallonge Moraine
1670
1700
Rocky L.
Silver L
Trout L.
1617
1670
Day L.
Boulder Mor.
Edith L.
Drumlin
1700
1635
Little Crooked L.
1685
Winegar Moraine
Crab L.
1650
1730
State Line
Ground Moraine Buried
Granite
Schist and Gneiss
100 Ft.
1 Mi.
Profile of Abandoned Logging Railroad
West of Boulder Jct. showing Outwash Terraces. Distances in hundreds of feet.
20 ft.
1000 ft.
W
Eroded Terrace 1620-1630
Little Papoose Cr.
Terrace 1640
Ravine
1630
700
600
Terrace 1630
1626
Rice Cr. 1591
Terrace 1600
Terrace 1625-1635
500
400
Esker
Coarse Gravel
High Plain 1660
Eroded Terrace
1630
Drumlin (Till)
Manitowish R.
1640
Outwash, sand and gravel
300
200
E
1653
Boulder Jct.
100
0

FIG. 2.

with vegetation, red clay, fine sand, and some ice-rafted bowlders were washed. In October 1927 a good example of this could be seen just west of the station at Winegar. The red color of the clay is probably due to its derivation from red Keweenawan and Huronian rocks to the north rather than to the plowing up of lake clays as in northeastern Wisconsin. The outwash streams from the Winegar Moraine also formed a plain lower than the higher portions of the Boulder outwash plain. The older moraines and outwash plains were extensively eroded and buried. This was done before the ice blocks had all melted. Little was left of the Boulder Moraine. The lower plain may be seen cutting across the higher plains along Highway 51 west of Trout Lake and southwest of Sayner. The main level of outwash from the Winegar Moraine is that seen at Boulder Junction (fig. 1). It was itself extensively terraced along Manitowish River by flow coming through the outer part of the moraine when the ice front had retired slightly farther north (fig. 2).

Postglacial. The glacial history of the area closes with the completion of the Winegar Moraine, for after that no more glacial drainage seems to have reached this region. This was due to the abrupt northward descent of the land north of the moraine in Michigan which diverted the waters to lower outlets than those across Vilas County. Since the close of glaciation the surface of the land in Vilas County has been altered by (a) erosion along some of the principal streams forming valleys with a maximum depth of 20 feet, (b) organic deposits in lakes and pools forming marshes, and (c) weathering which has kaolinized the feldspar of the sands to depths of one to three feet and has oxidized the iron-bearing minerals to much greater depths. In many places hydrous iron oxide has been redeposited in veinlets to a depth of more than five feet from the surface. These form irregular hard bands on the weathered surface of an excavation. In the red till region the color has been changed by hydration and solution to yellowish brown to a depth of two to four feet from the surface.

ECONOMIC GEOLOGY

Sand and gravel. Although the largest part of the area surveyed is underlain by outwash and other forms of assorted drift, good gravel is not common. Most of the outwash is fine sand. The best stony gravels are found in (a) outwash close to the moraines, (b) kames within the terminal moraines, and (c) eskers. The following list of pits is probably not complete, for small excavations near summer resorts may have escaped observation.

Location	Origin	Remarks
T. 40, R. 4 E. Sec. 24.	Kame (esker?)	—Large pit in poorly sorted gravels
T. 43, R. 5 E. Secs. 8. and 9.	Kames	—Several small pits in and near Winchester
Sec. 25.	Kame	—On road to Little Long Lake
T. 42, R. 5 E. Sec. 4.	Outwash	—Several pits in rather fine sandy gravel along C. T. H. "W"
T. 41, R. 5 E. Sec. 30.	Outwash	—Roadside pit on new road to Powell
Sec. 34.	Outwash	—Largest pit in area, ¼ mile long, 40 feet deep; used for filling by C. and N. W. R. R.
T. 40, R. 5 E. Secs. 18. and 19.	Kame or esker	—On town road to Flambeau Lake
Sec. 34.	Kame	—On Bolton road
T. 43, R. 6 E. Sec. 20.	Outwash	—On road to Crab Lake
T. 42, R. 6 E. Sec. 3.	Outwash or kame	—On road to Big Lake
Sec. 10.	Esker	—On Rice Creek road
Sec. 24.	Outwash	—On tail of drumlin on road to Big Lake
T. 41, R. 6 E. Sec. 17.	Kame	—On road to Flambeau; in part till
T. 40, R. 6 E. Sec. 14.	Kame	—Undeveloped cut on U. S. 51
Sec. 19.	Outwash	—On road to Flambeau
T. 43, R. 7 E. Sec. 27.	Kame	—Old railway cut on Blue Bill line
T. 42, R. 7 E. Sec. 6.	Esker	—On grounds of National Playgrounds Association

Location	Origin	Remarks
T. 41, R. 7 E. Sec. 26.	Kame	—On Sayner-Trout Lake road
Sec. 36.	Kame	—On Sayner-Trout Lake road
T. 41, R. 8 E. Sec. 27.	Kame buried in outwash	—On C. T. H. "S"

In addition to the above list there are many pits in the weathered surface of the outwash or "top soil" and a number in such sandy material that its use seems unwise. Many showings of what seemed to be good stony gravel were observed both along roads and in the brush, but as these were not confirmed by digging, they have been omitted. All the gravel is composed of hard crystalline pebbles and a few pebbles of sandstone. The gravels are inferior for both surfacing and concrete pavement to those found in limestone regions.

Water. Underground water supplies have been developed only to a very limited extent in the area surveyed. The railroad tank at Boulder Junction is supplied from driven wells in the outwash. Many summer resorts have shallow dug or driven wells, but others depend upon lake water. It is unlikely that large supplies could be developed at all points as coarse gravel is so scarce. In many places till may be found below the outwash and above the water table; in such situations little water could be obtained from wells. It is likely that considerable iron will be found in the ground water at most localities, for the forest mould and peat swamps undoubtedly dissolve a considerable amount of that substance.

Soils. The soils of the area here discussed have been described by Whitson, Dunnewald, and others[5] in connection with the controversy over reforestation. The map made for this report bears evidence of much careful and painstaking work but of very limited knowledge of geology. The following table represents the findings of the writer as to the true origin of the several soil series described in the report.

[5] Whitson, A. R., and Dunnewald, T. J., and others, Soil survey of Vilas and portions of adjoining counties: Wisconsin Geol. and Nat. Hist. Survey Bull. 43, 1915.

Soil Series	Origin
Plainfield	—Outwash, little pitted and only slightly weathered.
Vilas	—Outwash with a few kames and some terminal moraine where the till is covered with a few feet of sand; shows more alteration than the Plainfield soils.
Antigo	—Outwash, little pitted and considerably weathered.
Kennan	—Sandy loams, mainly terminal moraine, especially the rolling phase; level phase includes much deeply weathered outwash; silt loams not yet investigated in this area.

CONCLUSION

General. Although the present survey covered only a portion of the northern lake region, it is believed that it showed the general type of geology which exists throughout the area. Work over a much larger area will be necessary to connect the moraines into the general history of the recession of the Wisconsin ice sheet, but the problems of the origin of the lesser topographic features, such as the lakes, have been solved.

CHEMICAL ANALYSES OF LAKE DEPOSITS

CHARLES SPURGEON BLACK

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

INTRODUCTION

For many years the Wisconsin Geological and Natural History Survey has been studying the physics, chemistry and biology of the inland lakes of the State. Up to the present time the chemical work has been confined chiefly to quantitative determinations of the gases, organic matter and the various salts that are dissolved in the waters of these lakes; during the progress of these studies, the quantity and chemical composition of a number of aquatic organisms have also been investigated. The analyses presented here extend these chemical studies to the bottom deposits of a number of Wisconsin lakes and to three Alaskan lakes.

The collecting of bottom deposits for chemical and microscopical investigations was begun in 1918 and it has been continued more or less regularly up to the present time. During this interval a rather large collection of such material has accumulated; the chief aim, however, has been to obtain representative samples from the various types of lakes rather than to secure samples from as large a number of lakes as possible. In fact samples have been taken in only a relatively small percentage of the lakes visited during this period. The present analyses include only a small part of the material now in hand.

Most of the samples were obtained in the deeper portions of the various lakes; they were secured with an Ekman dredge so that they represent only the upper 12 to 15 cm. of the deposit. No attempt has been made to study the differences between the top and bottom portions of these samples. The bottom samples from the Alaskan lakes were collected by the late Dr. George I. Kemmerer during July and August, 1927.

This investigation was carried out under the direction of Dr. Kemmerer and the author wishes to express his indebtedness to him for assistance and helpful suggestions.

Methods

The samples were spread out and air dried as soon as possible after they were secured; this material was then put into bottles and jars and kept until the analyses were made. The air dried samples were ground in a disc mill and the moisture was then determined by drying in an electrically heated vacuum desiccator; the material was spread out on watch glasses in order to expose as much surface as possible and it was dried for ten days at 70° C. The drying was carried out at this temperature so as to avoid the decomposition of the carbonaceous material. In general the procedures given by Hillebrand[1] were used for the various chemical determinations.

Character of Water

The amount of salts held in solution by the waters of the lakes under consideration differs very widely. The lakes situated in southeastern Wisconsin possess relatively hard waters; that is, they contain comparatively large amounts of calcium and magnesium. On the other hand the lakes of northeastern Wisconsin and of Alaska have waters that range from medium hard to very soft, since they contain only medium amounts to very little calcium and magnesium. Table 1 shows the amount of residue, fixed carbon dioxide, silica, calcium and magnesium in the surface waters of the various lakes.

Determinations of silica, calcium and magnesium have been made on six of the lakes, but the amount of fixed carbon dioxide, or methyl orange alkalinity, serves to give a general idea of the degree of hardness of the water. The three lakes situated in southeastern Wisconsin, namely, Mendota, Monona, and Okauchee, with 70 to 75 mgm. of

[1] Hillebrand, W. F. Bul. 700, U. S. Geol. Survey. 1919.

fixed carbon dioxide per liter, are classed as hard water lakes, while Ike Walton, Long and Mary of the northeastern group with less than 3 mgm. of fixed carbon dioxide per liter belong to the soft water class; all of the others are intermediate, ranging up to medium hard.

Analysis of the Deposits

Table 2 shows the results obtained in the chemical analyses of the various deposits. The hard water lakes represent one extreme and the soft water lakes the other extreme.

SiO_2. In the three hard water lakes (Mendota, Monona and Okauchee) the silica constitutes from 28% to 36% of the dry weight of the deposit. In the soft to medium lakes there is a much wider variation; the range is from 22% in Ike Walton in northeastern Wisconsin to more than 69% in O'Malley, one of the Alaskan lakes, if the Forestry Bog is excluded. This small bog represents a special type of deposit and is not strictly comparable with deposits laid down in lakes. The three Alaskan lakes have a much higher percentage of silica than any of the Wisconsin lakes; this is accounted for by the fact that a very large proportion of the Alaskan deposits consists of diatom shells.

Fe_2O_3. There is a rather wide range in the amount of iron in the various deposits. It ranges from a minimum of 1.5% in Lake Laura to a maximum of approximately 9.5% in Trout Lake; both of these lakes are situated in northeastern Wisconsin.

Al_2O_3. The percentage of aluminum ranges from a minimum of 1.4% in Long Lake to a maximum of 9.5% in Silver Lake; both of these lakes also belong to the group situated in northeastern Wisconsin. The deposit from Thumb Lake, Alaska is a close second to Silver Lake, however, since it contains approximately 9.4% aluminum.

CaO. The analyses show very marked differences in the calcium content of the various samples. In the three hard-water lakes of southeastern Wisconsin calcium comprises from 20% to almost 25% of the dry weight; in the medium to soft water lakes of northeastern Wisconsin the percentage varies from a minimum of 0.6% in Long Lake to a maximum of 2.4% in Lost Canoe and Turtle Lakes. In the

Alaskan lakes the calcium varies from 2.1% in Karluk to 3.6% in O'Malley. Table 1 shows that the water of Lake Mendota contains two and a half times as much calcium as that of Trout Lake, but the bottom deposit of the former has fourteen times as much calcium as that of the latter. Also the water of Lake Mendota contains approximately twice as much calcium as the waters of the three Alaskan lakes, but the bottom deposit of the former yields from five to nine times as much calcium as the deposits of the latter. These facts seem to indicate that a relatively small increase in the calcium content of a lake water will produce a much more marked increase in the calcium content of the bottom deposit. The amount of calcium which gets into the bottom deposit is the result of complex chemical and biological processes, but it is very greatly influenced by the amount in the water.

MgO. Owing to the much greater solubility of magnesium, there is a comparatively small amount of MgO in the deposits of the hard water lakes as well as in those of the soft to medium lakes. In the former group the maximum is 3%, while in the latter it is 1.7%. In the three southeastern lakes the percentage of CaO in the deposits is from eight to fourteen times as large as that of the MgO; in the northeastern lakes the ratio of CaO to MgO ranges from a little more than one to almost sixteen and in the Alaskan lakes from about one and a half to three.

P_2O_5. There is about an eightfold range in the phosphorus content of the various deposits, but there is no significant difference between hard and soft water lakes in the relative amount of phosphorus.

SO_4. The smallest percentage of sulfate ion was found in Lake Laura and the largest in Trout Lake. Both of these lakes are situated in northeastern Wisconsin.

CO_2. As might be expected the three hard water lakes of southeastern Wisconsin show a much higher percentage of carbon dioxide than the medium and soft water lakes; in the former group the percentage ranges from 9.3% to 16.3% and in the latter from about 0.2% to 2.4%.

Organic Carbon. The amount of organic carbon in the various samples gives some idea of the relative quantities of organic matter in the different deposits. The samples obtained from the lakes situated in northeastern Wisconsin show the largest percentages; the organic carbon varies from 10.5% in Turtle Lake to 32% in Long Lake, excluding the Forestry Bog. In the samples from the lakes of southeastern Wisconsin the range is from 4.7% to 7.2% and in the Alaskan lakes from 4.4% to 8.2%. The Forestry Bog yielded substantially 39%.

In five samples of the surface deposit from different localities in Lake Balaton,[2] Hungary, the silicia varied from 1.5% to 54%, the calcium from 12% to 52% and the magnesium from 0.7% to 4.6%.

Decomposition of Bottom Deposit

An experiment was undertaken to determine how rapidly the organic matter in the bottom mud decomposes and also to ascertain the quantity and chemical composition of the gases given off during the decomposition. Two samples of mud were secured from a depth of 24 m. in Lake Mendota on October 21, 1927; they were transferred directly from the dredge to bottles. One bottle had a capacity of 4 liters and the other 5 liters; in both bottles the space not occupied by mud was filled with water brought up from the bottom in the dredge. Both bottles were placed in the dark during the experiment, but the 5 liter bottle was kept at room temperature and the 4 liter bottle in an electric refrigerator at a temperature of 4°. At the conclusion of the experiment the mud was dried and weighed; the 5 liter bottle contained 600 grams of dry material and the 4 liter bottle 690 grams.

Between October 21, 1927 and April 9, 1928 the material kept at room temperature in the 5 liter bottle (600 grams) produced 2597 cc. of gas, of which 297 cc. consisted of carbon dioxide and 1470 cc. of methane; the remainder consisted of hydrogen and nitrogen. No carbon monoxide or unsaturated compounds were found.

The sample kept in the refrigerator from October 21, 1927 to April 9, 1928 produced 593 cc. of gas, or only a little more than a quarter as much as the one at room tempera-

[2] Res. wissenschaft. Erforsch. des Balatonsees. Bd. I, T. 1, 17 pp. 1911.

ture. Of this amount 39 cc. consisted of carbon dioxide, 320 cc. of methane and the remainder of hydrogen and nitrogen.

TABLE 1. *The amount of residue or total solids, fixed carbon dioxide, silica, calcium, and magnesium found in the surface waters of the lakes for which analyses of the bottom deposits have been obtained. The results are given in milligrams per liter of water. Mendota, Monona, and Okauchee Lakes are situated in southeastern Wisconsin, while the other Wisconsin lakes are situated in the northeastern lake district. The Alaskan lakes are situated on Kodiak Island.*

Wisconsin Lakes.

Lake	Residue	Fixed CO_2	SiO_2	CaO	MgO
Adelaide	32	3.0	----	----	----
Forestry Bog	33	1.5	----	----	----
Ike Walton	19	1.2	----	----	----
Laura	34	10.0	----	----	----
Long	16	1.5	----	----	----
Lost Canoe	35	10.0	----	----	----
Mary	53	2.5	6.6	5.4	1.1
Mendota	192	70.0	3.3	33.6	37.6
Monona	240	74.0	----	----	----
Okauchee	212	75.0	----	----	----
Plum	55	17.0	----	----	----
Silver	48	15.0	----	----	----
Star	49	14.5	----	----	----
Trout	54	19.0	11.8	12.9	3.4

Alaskan Lakes.

Karluk	32	9.5	1.8	15.1	1.7
O'Malley	32	9.5	1.9	15.3	1.0
Thumb	34	10.5	3.2	17.0	0.6

TABLE 2. *Chemical analyses of bottom deposits. The results are stated in percentages of the dry weight. The depth of the water at the points where the samples were taken is indicated in meters. Mendota, Monona and Okauchee are situated in southeastern Wisconsin; Adelaide to Turtle inclusive, in northeastern Wisconsin; Karluk, O'Malley and Thumb on Kodiak Island, Alaska.*

Lake	Date	Depth	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	P_2O_5	SO_4	CO_2	Org. C
Mendota	Oct. 21, 1927	24 m.	36.32	4.67	8.28	19.88	1.85	0.36	1.92	9.32	7.05
Monona	Oct. 21, 1927	8 m.	28.15	3.20	8.98	23.32	3.01	0.42	2.60	16.00	6.57
		22 m.	36.50	2.32	5.34	20.40	1.44	0.93	2.62	14.32	4.72
Okauchee	Sept. 20, 1924	27 m.	31.26	2.47	6.49	24.70	1.68	1.39	1.53	16.33	7.22
Adelaide	July 17, 1926	19 m.	39.33	4.11	4.44	1.39	0.85	1.14	1.32	0.72	18.50
Forestry Bog	July 25, 1926	2 m.	9.35	1.33	0.80	0.76	0.50	0.24	0.66	0.00	38.95
Ike Walton	Aug. 4, 1927	18 m.	22.07	1.62	5.45	1.84	0.67	0.36	1.15	0.85	28.66
Laura	Aug. 9, 1926	12 m.	42.54	1.51	2.34	1.36	0.70	0.36	0.11	1.65	17.09
Long	July 28, 1927	12 m.	22.67	1.94	1.43	0.60	0.51	0.43	0.92	0.65	31.99
Lost Canoe	Aug. 5, 1926	12 m.	30.20	3.45	5.63	2.38	1.00	0.76	0.97	0.94	19.80
Mary	July 21, 1926	21 m.	33.50	1.56	1.78	1.90	0.51	0.72	1.76	0.47	26.92
Plum	July 17, 1926	15 m.	30.13	8.98	7.24	1.48	0.36	0.70	2.12	0.76	21.30
Silver	July 8, 1926	17 m.	30.68	2.14	9.56	1.72	0.11	0.18	1.30	0.22	21.30
Star	Aug. 21, 1926	18 m.	42.78	4.45	5.84	1.63	1.12	1.44	0.45	0.22	25.86
Trout	July 31, 1926	32 m.	41.29	9.47	1.79	1.42	0.83	0.56	3.92	0.34	20.27
Turtle	July 20, 1926	13 m.	40.70	5.23	5.19	2.44	1.35	0.89	1.05	2.36	10.54
Karluk	Aug. 13, 1927	120 m.	60.26	4.75	6.63	2.19	0.72	0.98	1.02	0.66	4.41
O'Malley	July 23, 1927	12 m.	69.42	4.18	3.63	3.67	1.50	1.31	1.09	0.77	8.22
Thumb	July 21, 1927	10 m.	58.12	6.24	9.36	2.58	1.73	0.99	1.73	0.19	6.37

NOTES ON THE CHEMICAL COMPOSITION OF SOME OF THE LARGER AQUATIC PLANTS OF LAKE MENDOTA. III. CASTALIA ODORATA AND NAJAS FLEXILIS

HENRY A. SCHUETTE AND HUGO ALDER

Contribution from the Department of Chemistry, University of Wisconsin, and the Biological Laboratory of the Wisconsin Geological and Natural History Survey. XXXII.

In earlier communications from these laboratories data were presented on the composition of some of the attached vegetation of Lake Mendota. Pertinent to these reports were an alga, *Cladophara*,[1] which attaches itself to the submerged rocks to be found along the shore-line in many places, and representatives of the larger plants. Among the latter were those which prefer a sandy soil, as the *Potamogetons*,[2] those which flourish in muddy situations, as *Myriophyllum*,[1] and those which thrive equally well in sandy soil as in mud, as *Vallisneria*.[2] Herein we record the composition of one of the species, *Najas flexilis*, which may be found in the shallow bays and which from the standpoint of abundance in this lake is exceeded only by *Vallisneria spiralis* L. and the Potamogetons; and of another which grows in sandy or in gravelly soils, *Castalia odorata*. The former has been reported as growing in water whose depth ranges from 0.3 to approximately 5.5 meters; the latter in water less than a meter in depth.

The species in question were part of the material collected by Rickett[3] in his determination of the quantities of the larger aquatic vegetation which are found in the region of plant growth in this lake, an area arbitrarily divided into three zones. All three zones furnished specimens of *Najas flexilis*, but only the first, or shallowest one, contributed the *Castalia odorata* L. The latter in the amount of 1,500 grams, representing 146 grams of dried material, was gathered from five stations in this zone. Of the former there were obtained 3,455 grams of the green plant which on drying yielded 384 grams.

Description of Plants

Castalia. The castalias, or more commonly the water-lilies, though world-wide in distribution are restricted to the northern hemisphere. Their grace and beauty have attracted man from the earliest time; they have given him an artistic inspiration in architectural design, and in India and in Egypt have from time immemorial entered into his social and religious life. There is evidence also that the seeds and tuberous roots of various species have been used for food by the natives of Australia, Madagascar, West Africa, and Central America.[4]

The long rhizomes of the castalia group creep along in or upon the muddy bottom of the lake in a tangle of vegetation. They branch in every direction, dying off behind as they advance by apical growth. Many of them have an erect stem. This never acquires any considerable length, however, for it stands with its apex about on a level with the mud in which its lower portion is buried. Many stout fibrous roots pass downward from the stem and anchor the plant in place while the leaves and flowers rise upward. The leaves lie flat upon the water surface, their upper sides being dry and exposed to the air. Under some conditions the petioles may be strong enough to hold up the leaves thus making them totally aerial. All of the species produce at certain periods of growth small thin leaves which lead a submerged existence. The flowers of about half of the species open at the surface of the water and seem to float upon it. Those of the other half are raised on strong peduncles some distance above the water-level. All have numerous petals arranged in many rows, the innermost gradually passing into the stamens. They are white, pink, yellow or blue and are very showy. Only in one or two species is cleistogamy known to occur. The flowers in such cases never rise to the air, or only do so for a few hours, after self-pollination has been effected. The fertile flowers, after anthesis, are drawn down into the water by movements of the peduncle and here the seeds ripen. The ripe seeds from the irregularly bursting fruits rise to the surface of the water by means of a buoyant aril and then float away far and wide.

Najas. The Najas are of no economic importance yet they have aroused much academic interest because of the simplicity and exceptional development of their floral parts. This genus is commonly referred to as the water nymphs, a name which appears to be inaptly applied to these humble water weeds.

The members of the genus *Najas*[5] are small, slender, branching herbs growing under water, with opposite and linear leaves which are somewhat crowded into whorls. The former are spinulose-toothed, sessile and dilated at the base. The flowers, which are dioecious or monoecious, are very small. They are carried without a foot-stalk in the axils of the leaves. Pollination is accomplished through the water in which the plants grow. The fruit is a small seed-like nutlet. It is enclosed in a loose and separable membrane.

Chemical Analysis

The material was made ready for chemical analysis by the procedure which has been described previously.[2] It was analyzed by the methods of the Association of Official Agricultural Chemists[6] which have been standardized and require no description here. Manganese was determined colorimetrically and the alkali metals were separated by the perchlorate[7] rather than by the platinic chloride method. Sand, which was considered to be extraneous matter, was determined in each species and correction made for the amount found. There proved to be 9.60 per cent in the *Najas flexilis* sample and 1.73 per cent in *Castalia odorata.*

The analytical results (tables 1 and 2), which represent the averages of duplicate determinations, are expressed on a sand-free and air-dry basis. The latter condition implies the net results of desiccation in the air and oven-drying at a temperature of 60°C. During the six-year interval which elapsed between collection and chemical analysis, the material in question had been stored under conditions which prevented the absorption of moisture.

TABLE 1. *Proximate composition of Castalia odorata and Najas flexilis L.*

Constituent	*Castalia* (Sand-free	*Najas* basis)
Ash	11.21%	19.16%
Crude protein (N x 6.25)	17.38	11.62
Ether extract	2.54	1.63
Crude fiber	19.70	18.41
Pentosans	11.95	8.45
Nitrogen-free extract	37.22	40.23

TABLE 2. *Inorganic constituents of Castalia odorata and Najas flexilis L.*

Constituent	*Castalia* (Sand-free	*Najas* basis)
Silica (SiO_2)	0.32%	1.89%
Ferric oxide (Fe_2O_3)	0.09	0.40
Aluminum oxide (Al_2O_3)	0.08	0.25
Manganomanganic oxide (Mn_3O_4)	0.09	0.05
Calcium oxide (CaO)	1.89	8.56
Magnesium oxide (MgO)	0.75	1.61
Sodium oxide (Na_2O)	1.20	1.05
Potassium oxide (K_2O)	2.72	2.19
Chloride (Cl)	0.40	0.51
Sulfur (S)	0.37	0.48
Phosphorus (P)	0.27	0.30

An interpretation of these data can perhaps be best approached from the standpoint of the relative amounts of mineral matter which each species annually requires for growth, and, in a sense, removes from the lake floor only to return part, if not all, of it in the final stages of its life cycle as soil constituent.

Rickett[3] has estimated that in the zone of plant growth in Lake Mendota—an area of approximately 1,040 hectares —there are annually produced 40 metric tons of *Najas flexilis*. On reducing this weight to a dry basis and translating it into terms of mineral matter, referable to the ash content found, it follows that this species annually requires some 7.6 metric tons of inorganic constituents for growth. This is less than the drain made upon the soil and waters of this lake by *Vallisneria* and *Potamogeton*[2]. A reinterpretation of data[1] previously reported brings out the fact that the annual requirements of *Najas* in Lake Mendota exceed those of *Cladophora*; although the latter contains more mineral matter, yet it is here less abundant. On the other hand, *Najas* removes only about 45 per cent as much inorganic material as does *Myriophyllum*[1] whose ash content (20.72 per cent) is approximately the same. Quantitative data on the distribution of *Castalia* are incomplete in the sources[3] which furnished the above information, hence a similar comparison can not be made for this form.

As for the species pertinent to this communication, it may be said that the order of magnitude of the content of alkali metals, chloride, sulfur, and phosphorus is substantially the same; that *Najas flexilis* annually requires more iron, aluminum, calcium, and magnesium salts than does *Castalia odorata,* but that the latter stores up more maganese than does the former.

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A NOTE ON THE CHEMICAL COMPOSITION OF CHARA FROM GREEN LAKE, WISCONSIN

HENRY A. SCHUETTE AND HUGO ALDER

Contribution from the Department of Chemistry, University of Wisconsin, and the Biological Laboratory of the Wisconsin Geological and Natural History Survey. XXXIII.

Little published information on the chemical composition of *Chara* seems to be available except a statement from botanical sources[1] that a species of stone-wort, *Chara foetida,* was found to contain potash, soda, lime, and silica in the amounts of 0.2, 0.1, 54.8, and 0.3 per cent, respectively. In view of the incomplete state of these data we have been prompted to fill the existing gaps by reporting the results of a chemical analysis which we made of a typical member of this order.

An opportunity of securing representative samples of *Chara* from Green Lake, Wisconsin, presented itself through the activities of Rickett[2] who made a survey of the annual crop of higher plants of this body of water in 1921. He observed that it is the dominant plant in the vegetation of this lake and reported that it may be found growing almost everywhere, sometimes mixed with other plants, and often standing alone in such dense masses that no other form has been able to obtain a foothold. This condition stands in marked contrast to that which obtains in Lake Mendota, it is stated, for here *Chara* plays but a minor rôle in the attached flora. Rickett advances the opinion that this situation may be traced not only to differences in the character of the respective lake floors, but also to differences in the transparency and temperatures of the waters in question. The waters of Lake Mendota are warmer and less transparent than those of Green Lake. The floor of the latter is covered with a fine marl in contrast to a mud which is characteristic of Mendota's bottom. Differences in the chemical composition of the waters of these lakes are not such as to be conspicuous, hence this condition is probably outside the scope of the discussion.

DESCRIPTION OF THE PLANT

Members of the genus *Chara* are popularly known as the stoneworts because they are incrusted with a calcareous deposit which, it is believed, serves them as a defensive armor. They are brittle and rough to the touch.

The most common species of this group is *Chara fragilis*[3]. It is wide spread in its distribution. The plant is about twelve inches high and consists of an axis with whorled, long, spiny, leaf-like structures at the nodes.

It reproduces vegetatively by outgrowths or sexually by the formation of motile sperm cells. The sexual structures are borne on the whorled branches at the nodes. Here are found oögonia, each containing a large egg cell which is visible to the eye because of its orange-red color. Beneath the oögonia at the same nodes are found antheridia which produce a large number of motile sperm cells. These enter the oögonia through an opening at the top and after fertilization a resting spore (oöspore) is produced.

It is probably not incorrect to state that these plants have never been used for any practical purposes, yet very good reasons suggest themselves for their use in correcting the acidity of sour soils.

Others, however, of the so-called worts have had at one time an economic importance. It may be pertinent to recall, in this connection, that it was to the members of the genus *Salsola* or saltworts that soap makers of early days in Spain turned as a source of alkalies long before the development in France of the well-known Le Blanc process for producing soda from common salt. The saltwort was here burned for its ash because the latter is relatively high in soda. This ash, which was known as "barilla", was then lixiviated with burnt lime whereby a solution of caustic alkali was obtained.

Chemical Analysis

The material which was made available for analysis represented the harvest from 38 collecting stations which were variously located in the zones of plant growth—an area comprising here some 8,570 square kilometers—over which the depth of water ranged from zero to eight meters. It had been air dried and then further dehydrated in an oven maintained at a temperature of 60°C. During the five-year interval which had elapsed between collection and chemical analysis, it had been stored in closed containers. Extraneous matter, such as shells, stones, sand, etc., was removed by hand after which the dried plant was comminuted in a drug mill to pass through a sixty-mesh sieve. Iron introduced during the process of milling was removed with an electro-magnet.

The analytical procedures of the Association of Official Agricultural Chemists[4] for the determination of organic and inorganic plant constituents and that of carbon dioxide in baking powder were followed with one exception, and that was the method of separating the alkali metals. The perchlorate method of Schlössing-Wense[5] was substituted for the official platinic chloride procedure. They are standard methods which require no description here.

Sand was found to be present to the extent of 0.89 per cent. In as much as this may very well be considered an impurity, analytical data subsequently obtained were corrected to a sand-free basis. They are reported on "as received" or air dry basis under conditions which have been outlined in preceding paragraphs. They are recorded in the following tables.

TABLE 1. *Proximate composition of Chara.*

Constituent	Percentage Sand-free air dry basis
Ash	41.22
Crude protein (N x 6.25)	4.50
Ether extract	0.76
Crude fiber	9.32
Pentosans	4.70
Nitrogen-free extract	39.50

TABLE 2. *Inorganic constituents of Chara.*

Constituent	Percentage Sand-free air dry basis
Silica (SiO_2)	0.83
Ferric oxide (Fe_2O_3)	0.06
Aluminum oxide (Al_2O_3)	0.81
Manganomanganic oxide (Mn_3O_4)	0.08
Calcium oxide (CaO)	37.82
Magnesium oxide (MgO)	1.19
Sodium oxide (Na_2O)	0.35
Potassium oxide (K_2O)	0.58
Chloride (Cl)	0.29
Carbonate (CO_3)	39.00
Total sulfur (S)	0.27
Total phosphorus (P)	0.06

It is generally accepted that the nature of the mineral salts in a water, in a plant or its products is to a certain extent a matter of conjecture since the salts found by analysis of the ash of the material in question are not exactly the same as those present in the uncalcined sample. These limitations make impractical the assignment to hypothetical combination of the acidic and basic oxides which are recorded in the foregoing tables. These data, however, admit of certain gross generalizations of which the following appear worthy of comment.

That the name stonewort which popular usage associates with this plant is well taken becomes apparent upon analysis of the data in tables 1 and 2 and by comparison with that obtained in the study of other forms of aquatic vegetation [6, 7] from Lake Mendota. *Chara* contains less nitrogenous matter, less cellulosic material and a lower carbohydrate content, referable to crude fiber and pentosans, respectively, than do *Vallisneria, Potamogeton, Myriophyllum* and *Cladophora.*

The fact that *Chara* contains, with some exceptions, a lower content of silica, iron, aluminum, maganese, magnesium, sodium, potassium, sulfur, phosphorus, and chloride than do the other vegetative forms in question is not so striking as that calcium oxide constitutes approximately 92 per cent of its ash. The value obtained, 37.82 per cent, is not in agreement with that reported from other sources[1], yet this apparent discrepancy has no particular significance of itself since the history of the material in question and the conditions under which it was grown, gathered, and analyzed are obscure.

Parallel with a high content of calcium oxide lies the quantity of carbon dioxide which the dried plant yields on treatment with acids. If one assumes that all of the carbonate in this plant exists here in chemical union with calcium and translates the quantity of carbon dioxide found into terms of calcium carbonate, there is obtained a value for the latter of 65 per cent. That this assumption, whereby is established the order of magnitude if not the exact quantity of the calcium carbonate content of *Chara,* is not seriously in error is established by the fact that the actual amount of calcium oxide found by analysis is approximately equal to that required by theory. On deducting the calcium oxide content of the ash from that required by the calcium carbonate of the incrusted deposit (36.40 per cent) there remains 1.42 per cent to be assigned to other acidic oxides.

Birge and Juday[8] state that Rickett's survey[2] indicates that about one half of the annual crop of higher plants of Green Lake—some 1,528 metric tons—is contributed by *Chara.* On correlating this observation with the values reported herein it would seem that the annual growth requirements of *Chara* for its major constitutent are 397 metric tons of calcium and 427 metric tons of carbon in terms of carbon dioxide. There are returned every year to this lake 993 metric tons of calcium carbonate.

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LIFE AND LETTERS OF EDWARD LEE GREENE

ANGIE KUMLIEN MAIN

Edward Lee Greene was born at Hopkinton, Rhode Island, August 20, 1843. In his early boyhood his family moved to Albion, Wisconsin and settled near the Seventh Day Baptist Church, of which they were devout members. He attended Albion Academy, but at the end of his junior year in 1862 he, as well as his father and two brothers, joined the Union army; at the close of the Civil war he returned to Albion Academy and graduated with the class of 1866, receiving the Ph. B. degree.

Not far from Albion, near Lake Koshkonong, lived Thure Kumlien, a naturalist of the old school, who became Edward's first teacher in the science of botany. A warm and lifelong friendship developed between teacher and pupil, which lasted until the death of the former in 1888.

From 1867 to 1870 Edward taught school at Monticello, Illinois, where he kept up his botanical studies. In the latter year he went to Colorado, where he studied for the ministry and was ordained in 1871. He was instructor in botany at Jarvis Hall, Golden City, Colorado in 1871–72, after which he was rector of churches at Greely, Pueblo, and Georgetown, Colorado, and at Berkeley, California until 1882. He became connected with the department of botany of the University of California in the latter year and remained there until 1895, serving as Professor of botany during the last five years. In 1893 he was President of the International Congress of botanists which was held at the Chicago World's Fair.

In 1895 he became professor of botany in the Catholic University of America, Washington, D. C., where he remained until 1904; he then became associate in botany at the Smithsonian Institution. During the twenty-five years that he was in the west he devoted himself to an extensive study of the western flora. His descriptions of his collecting trips through the Rockies, over the plains of Wyoming, through California, and away to the borders of New Mexico teem with interest. He discovered and described many new species of plants. He was the author of several books and of numerous papers which were published in scientific journals.

When Edward Lee Greene left home to enter the Civil war, a correspondence was begun with Mr. Kumlien, which continued for a period of twenty-six years. The following letters have been selected from this correspondence and they show his fine character, his love for the beautiful, his appreciation of the truth, his love for his revered teacher, and his gradual advancement as a high authority in botany. In these letters, Mr. Greene used only the scientific names of the plants mentioned, but the common names have been added in parentheses in many instances.

Dover, Tennessee, Sept. 10th, 1862.

Dear friend Kumlien:

I am seated in my tent this afternoon to write you a few lines to inform you that I am in the land of the living away down in Tennessee. I have been on the march for the most of the time since I arrived in Dixie and have today returned from an expedition to Clarksville, a distance of about thirty-five miles. We went for the purpose of expelling the rebel forces from that place and met them four miles this side. Our artillery attacked them and routed them after firing about one hundred shells and a few balls. We were so far from them that none of our men were seriously injured. Neither our infantry nor cavalry were allowed to fire at them at all but I think our musket balls would have reached very easily if we had fired. Our forces amounted to about twelve hundred and the rebels consisted of four or five hundred soldiers and a great number of citizens armed mostly with shot guns loaded with buck shot. We do not know exactly how many of them were killed, but the negroes who were present tell us that they estimated their loss at upwards of one hundred killed and wounded. Our men in passing through the orchard (they were concealed in a peach orchard when we attacked them) after they supposed they had removed all their dead and wounded found two who were most terribly mangled, one had his head severed from his body and another was torn in two. They lay side by side and probably were both killed by the same merciless bomb shell.

I have seen a great many new things in the vegetable world since I left home but it has not been much more than an aggravation to me to see when I could not have a chance to collect anything. But as we shall probably remain here a few days I will try to send you a few *Filices* (ferns) for I have found five or six new species here on the rocky banks of the Cumberland river. Some of them are small and beautiful and one very interesting one which is called the walking fern. The frond is entire and the end bends over and after taking root sends up another. I think the common name is very appropriate. I did not expect to find many flowers at this season of the year, but I have seen quite a large number while on the march. There are some pretty *Labiates* (mint family) and composites yet in flower and many species of *Desmodium* (tick trefoil). These southern forests must be delightful in early summer.

There are a great many handsome flowering trees here. The magnificent *Liriodendron tulipifera* (tulip tree) is quite common and also *Catalpa bignonoides* (catalpa) and an *Aesculus* (horse chestnut) all large trees.

Among the smaller trees the *Cornus florida* (flowering dogwood) and *Cercis canadensis* (redbud) are very gay when in bloom, especially the latter. The *Castanea vesca* (chestnut) is also common and the beech and several species of *Quercus* (oak) are new to me. One has leaves perfectly entire and two or three have leaves simply dentate. *Plantanus occidentalis* (sycamore) and *Laurus sassafras* (sassafras) and the gum tree are also large trees. Many of the forest trees are entirely new to me. The *Philadelphus* (mock orange or syringa) which we cultivate grows wild in abundance along the Cumberland.

I have succeeded in collecting a few seeds and will try to send them to you before long. I have also pressed two or three plants in a book. I will send you one or two in this letter. They are not beautiful nor even perfect specimens, but one of them is a climbing plant which I took at Cairo, Illinois. I have not seen any more like it since, but I examined the flower and the fruit which was not then mature and I think it belongs near the genus *Accerater* (green milkweed). Another is an *Euphorbia* (spurge). The piece which I am sending resembles *E. maculata* (milk purslane) but the plant is much larger and nearly erect and lacks the spot on the leaf. The other is *Lespedeza* (bush clover) I suppose.

I have not seen many birds except turkey buzzards. I am not as much of an ornithologist as I hope to be if I live. I will not attempt to write anything about the birds for I know you will be tired when you have read this letter, for I am at best a poor writer and am now writing under very unfavorable circumstances, so I will draw to a close. Give my best regards to Mrs. Kumlien and Sophia and remember me as your friend,

EDWARD L. GREENE.

Ft. Henry, Tennessee, (Written in the fall), 1862.

Dear friend Kumlien:

It is a lonesome, rainy day and I thought it would be very pleasant to have a social chat with you for a few hours. But as that cannot be I will try and write you a few lines to pass away the time.

We are at present encamped on the bank of the Tennessee river at what is called Ft. Henry, but it is only an opening in the woods.

There is no village here at all nor so much as a farm house within two or three miles. We have been here about two weeks and I have had a chance to search the woods a good deal.

I presume that the season of flowers is nearly passed in Wisconsin by this time, but not so here. It is very warm yet in this section and quite a large number of flowers are yet to be found and some very beautiful ones.

I found a species of *Chelone* (turtlehead) while walking in the woods. I consider it the most beautiful of anything I have seen. It differs from the Wisconsin species in that it is not so tall, but more branching and bears a profusion of rich purple flowers. It is a pretty large plant, but I shall endeavor to press some small branches and send them home. I have a book which I keep in my knapsack in which I can press small plants quite well. I sent a few home about a week ago and wrote mother to divide them with you. I shall send some more in a few days. I suppose you have had a good time with the Asters, *Solidagos, Gentians* and *Gerardia* this fall. There are few of them here. I have not yet seen a *Gentiana* (gentian).

The Gerardias are very handsome here; *G. purpurea* and *G. setacea* grow large here and flower very profusely. I saw a new species while on the march from Fort Donelson and think it must have been the *G. pedicularia* (fern leaved foxglove) if that is the correct name. It was not so tall as *G. quercifolia,* more branching and the leaves, which resemble those of the *Pedicularia,* clothe the branches very thickly. It was pretty, but I did not dare to leave the ranks to notice it closely.

We have taken a tramp of sixty miles south since we came here. We went up the river on the steamboat to Cherokee landing which is about forty five miles and then we marched the rest of the way. We camped at noon near a creek in the woods and there spent the remainder of the day. And being in a new place I of course took a tramp as soon as I was rested. I there found *Mitchella* (partridge berry) in abundance growing on the bank of the creek. Here I also found the beautiful *Rhododendron nudiflorum* (purple azalea) which was an old Rhode Island favorite of mine. How I wished it had been in flower, but I could not find even as much as a seed for they were all gone. I also found a *Vitis* (grape) with small leaves and very large fruit which was ripe and of an excellent flavor.

I will now tell you something about a coniferous tree which I have found in the woods here at Ft. Henry. Whether it is an evergreen or not I can not yet say, but I think it is not. It bears the fruit on the upper part of the tree and the branches which bear the fruit have a different foliage from the rest of the tree. This is one curiosity of the tree, and another is that under the tree conical stumps arise from the roots, some to the height of three feet, but of all sizes. They appear like a group of small mountains. If I were an artist I would draw a picture of the tree for it is very strange. I will send you some twigs of this tree soon. Perhaps you can tell me what it is.

I want you to please write me a letter when you receive this and tell me how you prosper. If you will call on mother she will give you some of the specimens which I have sent. I am going to send some more in a day or two. I do not find much now for it is too late in the season. But if we are so unfortunate as to be kept here until spring, I expect to have some pleasant times, but I hope that I will be in Albion next spring in time to gather *Arethusa* and *Pogonia* with you from that blessed little tamarack marsh.

We hear good news occasionally of victories on our side and may the God of wars grant that the final victory may soon be won and peace once more reign. For this war is ruining the best young men of our land. I find that a great change has taken place in the young men with whom I was acquainted. They are losing all taste for intellectual enjoyments and spend their hours in gambling and indulging their vile appetites. Well I see I have written you a long and tedious letter and I doubt your ability to read such a mess of scribbling for I have to write under very unfavorable circumstances. I will enclose you a picture which you may remember when you see it as your sincere friend and well wisher.

EDWARD L. GREENE.
Co. H, 13th Reg.

Ft. Henry, Tennessee, Nov. 16th, (I think the year 1862)

My dear Friend:

It is Sunday morning and I have seated myself to try to pen a few lines to you, although my stock of news is small and I fear it will not prove very interesting. I suppose you have had some winter weather in Wisconsin by this time. It begins to look like autumn here now, although the weather is very warm and pleasant during the day, but the nights are frosty. The leaves are falling from the trees and leaving them bare except now and then one whose branches are covered with mistletoe which is yet green. Is it an evergreen or not? It is indeed a very curious plant growing on the living branches of other trees. Mother has received two small twigs which I sent to her by mail and I presume that you have one of them by this time. When you write again please give me its Latin name.

There is almost any quantity of nuts and acorns now in the woods and a great many different species of both. I sent leaves of two species in my last package of flowers and was intending to send fruit of both with the seeds which I sent you by father, but I found him just ready to start when we returned from our last expedition and had no time to get them before he started. I think I will take a tramp in the woods before long and collect some nuts of all the new species and put them in my knapsack for it would be quite a novelty in Wisconsin to see some of these monstrous acorns and hickory nuts which grow here.

Well, I guess I must lay aside my writing for the present and prepare to attend religious services which commence at ten o'clock.

We have been on the march for the most of the time since I last wrote you and consequently I haven't had much chance to collect seeds, and the bottle of insects which I attempted to fill would not amount to much for it is now too late.

I sent all the seeds I had by father, but I had to do them up in such a hurry that I could not mark them as I had intended to, for I knew the names of some of them. One paper contains seeds of *Plantago lanceolata* (rib grass), a common biennial in New England. Sow some of the seeds in your garden for I think they will become naturalized. It is very different in appearange from *P. major* (common plantain). In another is *Cassia marilandica* (wild senna) and another is an annual species of *Cassia* (senna). I think I sent specimens of it home. Another is a perennial *Polygala* (milkwort). One contains seeds of a shrub which I suppose to be a *Hypericum* (St. John's-wort); it resembles that genus in every particular except that it is woody. I enclose some of the capsules in the paper so that you will know it I think.

I will collect some more seeds if I have an opportunity, but it is rumored that we are to start out on another expedition soon; but I hope it will not prove true for I am quite tired of running about after the little squads of guerrillas for they are all on horses and it is almost impossible for us to catch them on foot and they always escape us by flight. However, on our last trip we managed to overtake them as they were secreted in the woods getting their supper. They were about five hundred in number and our force happened to be superior to theirs. They mounted their horses as soon as they were aware of our approach and fired on us as they fled, but we returned the fire, killing sixteen of them and wounding thirty or forty. None of our regiment were seriously injured but several of the Iowa cavalry were killed and wounded. We took I think about twenty prisoners which we left at Fort Donelson as we returned.

During the short time which I have been in the service I have had a chance to see a good deal of Kentucky and Tennessee and have seen many places where I have thought it would be very pleasant to spend a summer. The most romantic road which I have yet traveled is situated between Ft. Donelson, Tennessee, and Hopkinsville, Kentucky. On the other side of the Cumberland as we leave Ft. Donelson for about five miles the road runs through a deep ravine. On one side of the road runs a stream of clear water which has its source in a large spring at the upper end of the ravine. It increases in size as it flows southward, other springs among the rocks contributing each its share of clear, cold water to the beautiful stream. The rocks on its edge are covered with mosses and higher up the ferns are still green and beautiful, although in some places they are nearly buried with the leaves which have fallen from the trees above them. I thought as we marched along that it would be a beautiful place in May or June and doubt not there would be many new things there for you and me.

I am enclosing some specimens of a beautiful little grass which grows along the river. It is all I have to send this time except my best wishes to yourself and family. Hoping that this rebellion may soon be ended and peace restored, I remain,

Your sincere friend,

EDWARD L. GREENE.

Write as soon as convenient and excuse my hastily written letter.

Ft. Donelson, Tennessee, March 12, 1863.

Dear friend Kumlien:

Yours of March 1st was received this morning with usual welcome and read with pleasure. I excuse you of course for not answering every letter of mine, knowing that you are otherwise engaged. I am glad that you are ready now to begin the labors of another season and wish you eminent success and regret that I cannot share the pleasure of roaming about the prairies, woods, and marshes of old Wisconsin with you. But I shall remain contented with gathering what I can from Tennessee during the coming season and trust I shall find many new things if we remain here. Since I last wrote to you we have been removed from Ft. Henry and have taken up our abode at this place and shall probably remain here for some time to come. At least so long as there is any danger of another attack being made, which there is at present. Father has been with us for several weeks now. I thank you for the compliments you sent by him, but I don't think there is any great prospect of my becoming eminent as a naturalist, situated as I am with nothing but my own hands and nature before me. But as I love the study I shall give all my leisure to it and the pleasure of the passing time will be enough to repay me for my labors. Father brought me a new work, one which mother procured for me, namely, "Principles of Zoology by Agassiz and Gould," a very interesting book to me and one which has already given me many new ideas of nature beyond botany. Should I ever be relieved from my present situation, I shall pursue the study of the animal kingdom as eagerly as I do botany at present.

Spring is very evidently with us now. *Hepatica triloba acuta* is in flower. I never saw any flower appear more romantically situated than this little plant as it grows in crevices of the huge and almost perpendicular masses of rock which rise from the south bank of the river. High above the reach and among the verdant mosses this little herald of spring now shows its flowers, all of which are white. I have seen no blue ones. Also *Anemone thalictrordes* (rue anemone) is in flower on sunny hillsides in the woods, not so common as in Wisconsin and rather larger. *A. nemorosa* (wood anemone) I have not seen and doubt whether it grows in this latitude. I find also with *Hepatica* by the river a new plant, a specimen I will enclose. From its resemblance to *Saxifrage pennsylvanica* (swamp saxifrage) of Wisconsin I think it is a saxifrage, but don't know for I have almost forgotten the character of the genus.

Other plants (new to me) will soon be in flower, among them a phlox which is almost ready. I also received a letter from Prof. Wood this morning. It was in reply to one which I wrote him for information about getting a flora for this season's use. The new class book seems to be the one I want and he kindly offers to send it to me postpaid for two dollars, although since the rise in the price of paper the retail price of the book has been raised to two dollars and a half. His chirography so closely resembles yours that before I opened the letters I supposed them both from you. He writes a good, sociable letter—says he has tramped about this forest and hill with box, press, spade and compass and says it is a very rich field for botanical researches.

I will send his letter to mother and if you wish to see it you can do so by calling at mother's. He gives the same name to that fern which you do. Mother writes that one of her cacti is preparing to flower. I will collect for you a bottle of insects as soon as they become plentiful. I undertook to do so last fall, but it was too late in the season. About the reptiles of this section, I think they are more numerous than at the north, especially snakes, which, according to what the darkies say, are venomous. I must try to send you some specimens of that flat little *lacertian* called the "swift." It is quite common among the rocks along the Cumberland. I killed two last fall but could not preserve them, not knowing where to get the bottle of alcohol. But I think I can procure some little things of that kind at the hospital. I shall endeavor to make a collection of the shells of the Mollusca of the Cumberland if we remain in its vicinity until the river falls. I must close for this time, begging that you will excuse bad penmanship. Give my respects to your family and think of me ever as,

Your friend,

EDWARD L. GREENE.

Nashville, Tennessee, April 18, 1863.

My dear Friend:

I am seated once again to pen you a few lines, not because I have much to write, but I have a few specimens of an interesting little plant now pretty nicely dried and I want to send them before they get mouldy. I haven't a book with me so cannot tell you what the flower is, but you will readily find its name from the dried specimen. I should at first sight pronounce it a *Dicentra* were it not for the fact that only one of the sepals is hooded; it is quite a singular looking flower and I think belongs near *Dicentra*. It grows in just such localities as the dutchman's breeches usually do, but the root is very different from that plant.

Associated with it grows an *Urtica* (nettle). It is not more than six inches high and was in flower when I took these specimens, and today I am going to take specimens of it. I found a day or two since plenty of *Ranunculus pusillus* (spearwort) but not yet in flower. I have also, I think, found two new species of *Dentaria*, (toothwort or pepper-root); one of them is *diphylla* (toothwort or crinkleroot) I believe and the other is a very small *Dentaria* and is not yet in flower.

I have not yet been about in the wild lands much, but shall try to make a trip into the country soon. I may find a good many new things even here in the vicinity of Nashville.

Our regiment has been assigned to duty at this place and we shall no doubt remain here during the summer. About once a week I have to go to Louisville, Kentucky as train guard. On this road we pass within nine miles of the entrance to Mammoth cave. If it is possible I will go there to see the great cave. Oh how gladly would I have you with me if I am so fortunate as to go.

It will soon be with us here the pleasantest part of the year; already "frondent silvae" and the birds and wild flowers are here in plenty. But I suppose you have not collected many yet. May these lines find you in good health and ready to commence your spring labors. Please answer when convenient and give me the name of the enclosed plant. With my best wishes to your family and yourself, I remain your friend,

EDWARD.

Ft. Donelson, Tennessee, May 6th, 1863.

Dear Mr. Kumlien:

I gladly seat myself this evening to reply to yours of April 29th; glad to hear from you again so soon, and to know that you have resumed your labors for another season. I am still blessed with health and remain in the hospital quite well contented with my situation. Not many sick at present. I have my new book, thanks to Prof. Wood! It is, I think, a great improvement on the old edition. Said to describe all known plants, (lower Cryptogamma excepted) in the U. S. except those of South Florida and west of the Mississippi river. But I have taken specimens of an *Allium* (onion garlic) here in Ten nessee that is far from being described in the book and also an *Erigeron* (daisy fleabane) that I *think* is not. The descriptions are, I think, greatly improved in this edition and the number of genera is reduced greatly. *Pentalophus* is again united to *Lithospermum. Otophilla* to *Gerardia,* and many others have returned to where they belonged. It describes 186 *Carices* (sedges), 48 *Solidagos* (goldenrods) and precisely the same number of asters, which is rather singular. When the *Carices* come in fruit I shall find more species than I expected to. There is a very beautiful one growing on the rocks along the river with short leaves that are an inch broad, pale green, almost white and translucent near the base. Many interesting flowers are now appearing, *Bignonia capreolata,* (cross-vine) is just beginning to flower, a fine evergreen climber with large dark green, eliptical leaves and large yellow and red flowers. *Houstonia caerulea* (bluets, innocence) grows on dry ground and is smaller with very dark blue flowers. *Houstonia purpurea* (bluets) is handsome, with very delicate corollas, closely resembling those of *Mitchella repens* (partridge berry). *Cynthia dandelion* (dwarf dandelion) is handsomer than *Cynthia virginica* and bears a large tuber at the extremity of the root about an inch below the surface. *Silene virginica* (fire pink, catchfly) is the richest thing that I have yet found, very common, with large scarlet flowers. *Pyrus angustifolia* (crabapple) is more delicate than the Wisconsin crabapple, but at a distance it appears the same. I have at last found a little marsh of an acre or two, but it contains no flower except a small delicate *Scirpus* (bulrush). But it contains several plants that I do not find elsewhere; one of them I suppose to be *Geum rivale* (water or purple avens) has very handsome pinnate leaves, but no flowers as yet. You will find *Trillium grandiflorum* (large flowering trillium) almost anywhere in the woods between Clinton and Mr. Odell's. You will find it in the thick young timber in moist shady places. It is not half as large as the other species is here. *Trillium sessile* is the common one here. It is small and not remarkable for beauty. I will give you the name of most of the plants that I have taken on the opposite page and close. With my best wishes I remain,

Ever truly yours,

EDWARD.

(There follows a list of fifty-two plants which I will not enumerate here).

Ft. Donelson, Tennessee, May 12, 1863.

Friend Kumlien:

Yours of the 2nd inst. came to hand last evening and I am seated this morning to pen you a few lines more. I am obliged to you for your instructions and I shall do the best I can at collecting zoological specimens, but I do not know how much I shall be able to do in that line, but shall probably send you some new things. Wish I were able to stuff you some of our birds. I saw a red-headed woodpecker the other day as large almost as two yellow-hammers, mostly black except its red head. (The ivory-billed or pileated woodpecker). I have seen several of them, besides many others that I never saw in the north.

The *Euphorbia* (spurge) that I sent you is *E. commutata* I think without doubt. It is distinguished from all others by its "floral leaves, broader than long and so applied as to appear connate-perfoliate." I sent the whole plant except the root, but it is in fruit now, also still in flower, but appears very different from what it did when I took those. I shall preserve more when I go where it grows again. It is by no means common here. Flowers are increasing in numbers rapidly and they will get the start of me before long I fear. Yesterday I took a single specimen of *Phlox maculate* (wild sweet william). It surpasses any phlox I ever saw in beauty, *P. drummondii* of the gardens scarcely excepted. It is not very common here. Many very rich flowering trees and shrubs are now in flower; among the most beautiful are *Wisteria frutescens, Bignonia capreolata* (cross-vine), *Liriodendron tulipifera* (tulip tree) etc. *Pentstemon pubescens* (beard tongue) is in flower, quite handsome, and another species will soon be. I found a small and elegant *Desmodium* (tick trefoil) in flower yesterday, but could not determine the specific name with certainty without the fruit.

No orchids yet except *Orchis spectabilis* (showy orchis) and *Cypripedium pubescens* (larger yellow ladyslipper) both out of flower now. One plant which I had taken to be an orchid has flowered and I am "up a tree" about it. I cannot find it described anywhere yet. Certainly not an orchid but belongs to the *Melanthaceae.* It is not described there nor in any of the adjacent orders. A two foot high plant with a long nodding thick raceme of small, white fragrant flowers, *Hexandrous Monoggnous,* stem nearly leafless, radical leaves resembling those of *Dodecatheon media* (shooting star). Perhaps I shall find its name when the fruit appears. It is very common on high grounds and handsome. I have found a few specimens of *Aplectrum hyemale* (putty root) the only new orchid, but it is not yet in flower. The early flowering *Carices* (sedges) are now ready in fruit. I have taken specimens of *C. digitalis, C. steudelii,* and *C. careyana,* the latter a fine species with leaves an inch wide or more, in which respect it does not agree with the description of which says "6", but it differs greatly from *C. plantaginea* in other respects, but agrees in description of foliage.

I will send you a specimen of *Silene virginica* (fire pink) in this if my specimens are not all too large. Its bright flowers have faded in pressing.

I took a ride across the river last evening and found a new *Ranunculus, R. parviflorus* (creeping buttercup) a naturalized species from Europe. I think of no more this time except to give you the names of what I have taken since I last wrote to you. So good bye.

EDWARD.

P. S. Mother writes that several of her cacti are flowering this spring. Go and see them. I wish I could. Remember my love to your family all. We have just received glorious news from Virginia and we begin to hope for an end of the war very soon.

(There follows a list of thirteen plants).

Ft. Donelson, Tennessee, May 25, 1863.

Dear Friend:

Although I have not received an answer to my last, I must chat a little while with you this afternoon. I have just returned from a tramp in the woods. The weather is very hot now and walking in the middle of the day is very disagreeable. But still the flowers are increasing in numbers and I must try to keep up.

The composites are now beginning to flower. I saw two new ones to-day that were just commencing, but did not examine them for I have enough of others that are in full display and which will not wait for me. I came very near losing *Wisteria frutescens;* it is so uncommon and I have had so many ways to go. But today I took four specimens, but they are on the decline now. It is the most beautiful native leguminous plant that I ever saw. Its thick raceme of large blue flowers is often ten inches long.

Of *Bignonia capreolata* (cross-vine) I got only two specimens, one of them a very beautiful one and the other a poor one. Its flowers are large and very evanescent, or like those of some species of *Gerardia*, falling off when exposed to the sun for a short time. It is rather more common than *Wisteria*, but grows only in certain peculiar situations.

Tomorrow I must go after *Aplectrum hyemale* (putty root). It must be out now, but I know of only one specimen which grows about a mile and a half from here. I may find more. *Philadelphus grandiflorus* (mock orange or syringa) on the river banks is now in flower and *how* beautiful. I have found two new *Vaccinia*, *V. stamineum* (squaw huckleberry) and *V. arboreum* (farkleberry); of the former a small twig is enclosed, the latter is not yet in flower. I also enclose a *Verbena angustifolia* (vervain). It is the most common species here, growing in dry and open grounds everywhere. Wood says "corollas deep blue" but they are invariably pale blue.

The *Carices* (sedges) are coming on finely. The most common one I trace by the table to *C. vestivalis* very plainly, but it differs greatly from the description and I cannot determine its name. The *Aristolochias* (birthwort) are very interesting plants. *A. serpentaria* (virginia snakeroot) is quite common, but I have seen only one of *A. tomentosa* (similar to dutchman's pipe). The little *Ranunculus* enclosed I cannot name. It is not described in my book. Grows in a little pond with *Rumex verticillatus* (swamp dock). I have not found more than a dozen specimens.

Frasera carolinensis (american columbo) is a large homely plant, but would be handsome if the flowers were of some bright color. The flowers are in a large terminal panicle and are quite curious looking.

I will give you the names of what new ones I have taken since I last wrote you and close with my best wishes for your welfare.

EDWARD L. GREENE.

(A list of twenty-five plants follows).

Ft. Donelson, Tennessee, July 15, 1863.

Mr. Kumlien, my Friend:

As I have a little spare time this morning, I will try to write you a few words that you may know that I am well and still pursuing my favorite employment. Within a few days I have taken specimens of some very choice southern plants. Among them is the *Platanthera* enclosed. It is, I believe, *P. perzamaena* (fringed orchis) and the handsomest species that I have ever seen. It is quite common here along the streams in shady places, and with the exception of a single speciment of *P. flava* it is the only *Platanthera* that I have seen in this country. The enclosed specimen is a very small one, the smallest I could find, and notwithstanding I pressed with a hot iron the flowers have lost their color, which is a rich purple.

The little green *Liliaceous* flower, although it has no beauty to recommend itself, is not unworthy of notice. It is a flower of *Agave* *virginica* (false aloe) and I do not hesitate to say that it is the sweetest smelling flower that I ever saw. I have seen only one plant in flower. The scape is more than six feet high and the raceme of flowers about three feet long. This specimen stands about half a mile from where I am sitting and I go to it every evening to inhale its delicious fragrance. But before many days I shall have to go out and end it into specimens for the press. I hate to do it as long as there are any flower buds to open, but I must. I wish I could find more of it. It grows plentifully on the lime ridges around Ft. Henry. I saw its leaves and the scapes of last year there last spring. I am lucky in finding this one specimen here so I will make the best I can of it and remain contented.

Summer is rapidly passing away and the fall flowers are preparing to make their display. The *Gerardia* will soon be in flower.

I have taken specimens of *Seymeria macrophylla* (mullein foxglove) which is closely related to *Gerardia.* It stands next to *Dasystoma* in my book and you would take it to be a *Dasystoma* at first sight. It is a large bushy herb six feet high, very diffusely branching.

Another common and very beautiful little herb, *Sabbatia stellaris,* (sea pink) is just beginning to flower. The texture of the flower is very delicate and I cannot press it so as to have it look natural. Since I last wrote I have found another species of *Passiflora* (passion flower) *P. lutea,* a small and slender species; have no specimens pressed yet. *Ozydendrum arboreum* (sour wood) is now in flower in the woods and makes quite a show. It comes next after *Andromeda* and scarcely differs from that genus, except in its size and manner of flowering. It bears a large spreading panicle composed of numerous one sided racemes at the extremity of each branch. *Tecoma radicans* (trumpet flower), one of the most beautiful things that I have seen in the south, is in flower. It belongs in the order *Bignoniaceae* which is near to *Scrophulariaceae.* The flowers are large and beautiful in clusters at the ends of the branches. The corolla is two and one-half inches in length.

Mimulus alatus (monkey flower) takes the place of *M. ringens* (northern species of monkey flower) here. *Galium pilosum* and *G. circaezans* (bedstraws) are the most common species of this genus. I have taken a few specimens of *Aster oblongifolius.* It is the earliest species here. I don't know that I have seen it in Wisconsin, but perhaps it grows there. I will enclose a specimen of *Forsteronia difformis,* a slender vine and rare here. I have seen only one plant. It belongs to the *Apocynaceae* (dogbane family), next genus after *Amsonia.*

There are several species of *Desmodium* (tick trefoil) and *Lespedeza* (bush clover) in flower but I have not examined any of them except *Desmodium rotundifolium* which is a large spreading species. The *Desmodium* which bears leaves and flowers on different stems is preparing to flower. Yesterday I found *Plantago aristata* (plantain), a very small and singular looking *Plantago* with linear leaves and bracts attennated into long rigid awns.

I would like to know just where you are today and what you are doing. If our armies gain many more such glorious victories as we have recently been doing I think we may hope for and expect peace soon. I am making no other calculations than that I shall be at home to commence botanizing in your company next spring. Perhaps I shall be dissappointed but I think not. The news is cheering of late and I think the rebels are about whipped. It will soon have been a year since I enlisted, and how rapidly that year has passed away. I have met with no serious misfortunes, my health has been preserved and I have enjoyed my soldier life very well. I have seen many beautiful things in nature during my year's travels through the south. I am now ready to return to Wisconsin at any time when this war shall be brought to an end. I thank God for all his mercies and blessings which he has so kindly bestowed upon me and wait patiently until the time comes when I and all the rest engaged in this cause shall be permitted to return to our homes. I will close for this time with love to you and to your family and hoping soon again to enjoy intercourse with you all as in days past. I remain with all kind regards your friend,

EDWARD.

P. S. Please write as soon as convenient.

Huntsville, Ala., Jan. 4, 1865.

Esteemed Friend:

Your kind letter of Nov. 13th is before me, and I will endeavor to reply to it since railroad communications are once more, at least partially, opened between us. Your letter was a long time in finding its way to me, and perhaps this may be as long in finding you. Doubtless you are well aware that for a number of weeks past the position of Hood near Nashville has prevented any correspondence between us, and this is the reason why I have delayed writing to you for so long.

In the first place I must give you a brief sketch of my military experience since I last wrote to you, though I have not yet seen much of what the ancients call the "gloria belli." Amid all the recent fuss and fighting in our department, our regiment has not been called to take any active part. But we have indeed seen rather hard times, suffering from sore feet and weary bodies; short provisions have been experienced by many of us to an uncommonly oppressive degree.

I had well nigh lost all my botanical and other little collections on my last march. We were ordered away from Claysville soon after I wrote my last letter to you and were obliged to burn up a good many valuable things to prevent them from falling into rebellious hands after our departure. I managed to crowd most of my plants into my knapsack by carrying some of my clothing in another manner and have preserved now the most of them, and as soon as an express is opened, which I am informed will be soon, I shall send them home. We are perhaps permanently stationed here in Huntsville, the most beautiful little city I have ever seen. We have fine, pleasant weather since the commencement of the month, though we had cold rains and a few slight flurries of snow during the week intervening between Christmas and New Years.

Three weeks more and we shall have spring flowers! We had them on the first of February in Nashville last year, crocus and such early garden exotics.

This is probably my last winter in the U. S. Military service. I have only seven more months to serve. I think, however, that it may not be my last winter in the south if my life is prolonged. However, I do not think of ever taking up my abode in this part. I should by far prefer the opposite side of the Mississippi river somewhere. The climate of this southern latitude is so much better than those hyper-frozen regions, to my idea at least.

But I will cease from building these airy castles for the future since it is so impossible as you say for us to know what it will realize to us. I suppose we who acknowledge our dependence upon the merits of our Lord and Savior for our hope of eternal happiness should be more willing to submit to do His will when, where and however He may see fit, than to accomplish our own plans. Yes, certainly we must and we cannot exercise proper faith in Him unless we are willing and ready to prefer what may seem to be *His* will to our own. I am glad to perceive by your writing that your hopes of eternal felicity beyond this scene of strife and mortality are centered in the merits of the crucified Son of God, which I too believe to be the only hope for fallen and sinful humanity. And while it is a lamentable fact that none of us who have come to years of understanding, have not sinned and are not dependent upon the mercies of Christ; it is also a fact, a blessed one too, that His salvation is able to save even the most degraded sinners if they will but turn to Him and receive Him as their Lord and Savior. Let us see then that with an unanswering faith we rely upon Him and doubt not that He will save us and that none other can. I find that it is not sufficient that I assent to the fundamental articles of Christian faith, submit to the ordinances and sacraments of the church and abstain from outbreaking sins. All these of themselves do not rob death of its gloomy aspect, but these words, "God so loved the world that He gave His only begotten Son that whosoever believeth on *Him* should not perish but have everlasting life," are of themselves sufficient if I by faith apply them to my own case.

There was a time in the life of the lovely and noble Martin Luther, when these words of his *credo* "I believe in the forgiveness of sins" gave him no consolation though he thought he believed them. But when Staupits directed him to believe that not only were Paul's and Peter's sins but his own were forgiven, then it was that sorrow and gloom left him, and death was stripped of its terrible aspect, and he afterwards became what he was as a minister of the gospel, and reformer of the world. Pardon me if it may seem that I am writing a tedious letter, but let me say to you as a brother in Christ, do not only *hope* that Christ's mercy will extend to you, but *doubt not* that *it does*, for I believe it to be the privilege of us all to have no fear of death. All that is necessary to bring us into this blessed state is to let Christ be indeed our own personal Savior and Author of eternal life.

I must bring this to a close. The enclosed little lichens are some which I took on the bank of the Tennessee river at Claysville on cedar trees. I sought for more but they were evidently very uncommon. It is a species entirely new to me. Let me hear from you again when you find time to write. My best and kindest regards give to your family. God bless you and them is the prayer of your unworthy friend,

EDWARD.

Direct to Huntsville, Ala.

Huntsville, March 18, 1865.

Mr. Kumlien.

My dear Friend:

Before me lies your good letter of the 5th inst., which I will now endeavor to answer immediately, for tomorrow we move to commence our spring campaign. We are ordered to Knoxville, Tenn. and probably from thence we shall go into Virginia. Until quite recently we have been expecting to remain at this post during the season, but being unexpectedly transferred to the 4th army corps, which is on the move, our prospects are changed quite a good deal. It looks now quite possible that we shall see more severe service than we have done heretofore, and I shall probably have the pleasure of seeing new territory before I get home.

Last night I dreamed of seeing lofty mountains whose sides were clothed with the richest verdure of various kinds of trees and whose summits rose above the floating clouds. I thought that with Chaplain Foote I endeavored to ascend one, but it was so steep that I became extremely tired and then I awoke from my vision to find myself on the same couch where I have slept for two or three months past. But I am not sure but that I shall not at least partially realize my dream for it is said to be a very mountainous country through which we pass even on our way to Knoxville, and beyond that are several ranges of mountains. It will soon be the most delightful part of the year for traveling in this country. Trees are beginning to put forth their leaves. Peach and plum trees are in bloom, elms and maples in fruit. But it is rather strange that I find no new wild flowers yet. *Ranunculus recurvatus* (hooked crowfoot) *Taraxacum* (dandelion) and other flowers that are not the earliest in our country have been in flower here for weeks past. *Myosotis* (scorpion grass, forget-me-not) is the only plant I know of now in flower that does not grow in Wisconsin.

In the gardens now are innumerable varieties of crocus, hyacinth, narcissus, etc., etc., in bloom and the air is redolent with their fragrance.

Among the feathered songsters are the mocking bird and pine grosbeak that I believe we do not have with us at home. Both are beautiful and accomplished musicians, taught not by man, but by their creator.

I do hope that you may be permitted to prosecute your plan of a trip into Kansas. Judging from what our boys say of that country I conclude that you will find it a very rich place in both botany and geology. But shall I not be deprived of your correspondence during your absence from home? Probably this will be necessary for I shall not know where you are. *But* if you spend three months there, Providence permitting, I shall be at home again almost as soon as you will and may see what you found and enjoy a narrative of your expedition.

I say again I do hope you may go. By all means let me hear from you once more before you start. I am glad to hear that although your little ones have been unwell yet you by God's blessings have their health restored.

I thank you for your kind admonition with regard to abiding in close intimacy with God our Saviour. Although in nature we see many evidences of His love toward His creatures, but in the great book of His we have a still more wonderful evidence of His goodness. We have received the emblems of His broken body and shed blood and I trust a portion of His spirit also. So let us cultivate it while this life is given us so that death will be to us only the entrance to a true life, a glorious one! I am glad for your sake and for her sake and for the sake of God that you have a sister so able to give you counsel and cheer in the comforts of our holy religion. I say *our* religion for it is all the same in every fundamental principle and I with you can see no reason why you need leave the communion of the church into which you were baptized. With me it is all the same and I would willingly for the sake of harmonizing the great body of Christ's divided church consent to unite with the one to which you belong if it were expedient. I consider that every sect which does indeed build on the true foundation, i. e. Christ, is a part of Christ's church. The superstructures are more or less imperfect in different sects and which is more perfect I am unable to decide and so I conclude that it is not material to salvation that we belong to this or that denomination but are at liberty to unite our tastes and our judgment in this matter. But my Sabbatharian brethern say I am too liberal in these views for a Sabbatharian and doubtless it is so. Nevertheless I am not obliged to sacrifice what I believe to be the truth on that account. But I shall trespass on your patience, so good bye and God bless and prosper you.

Ever your friend,

EDWARD.

My kind regards for Mrs. K. and your children. Ed.

Camp of the 4th A. C. near Nashville, Tenn., May 2, 1865.
Mr. Kumlien.

My dear Friend:

Yesterday I was all day thinking about you and wondering whether you had yet set out for Kansas. I was expecting a letter from you and at night my expectations in that line were realized by the arrival of yours, bearing date of April 23, 1865.

I am partly sorry that you cannot prosecute your plans for a westerly trip for it would be such a pleasant one if it could be made with profit, and for the best part I am pleased with the hope that I shall have the pleasure of a social interview with you sooner than I should had you made the contemplated expedition.

We are all feeling quite confident that we shall be at home before the first of July, and we hope even sooner than that. Evidently the war is ended and every move seems now to indicate a speedy dismissal of a large number of troops. Even today soldiers are being mustered out here at Nashville.

Another year may afford a better sight for an expedition westward and allow me the delight of accompanying you! That is if we can arrange matters so that my presence with you would not be detrimental to your success, etc. etc. I have almost made up my mind that I would make my home somewhere in that trans-Mississippian region though possibly farther to the southward than Kansas.

Well I have done some traveling and seen some new country since I last wrote to you. Our Corps started from Huntsville about the 20th of March for Lynchburg, Va., for the purpose of assisting in the capture of Lee should he vacate Richmond and endeavor to escape to the west. We had proceeded but half way, however, when we received the intelligence that Lee had surrendered. Our Brigade went as far as Jonesboro in the northeastern part of Tennessee, the remainder of the Corps stopping at other places in the rear of us. At Jonesboro we remained two or three weeks, and then were ordered to Nashville. We came back by railroad most of the way and here we remain and probably we shall be kept here until mustered out. At Jonesboro, Tennessee we were encamped in a full and delightful view of the great Smoky Mountains of North Carolina, but the nearest point of the mountains was twenty miles distant and of course a visit was impracticable. But you will easily imagine with what longings of heart this child used to stand and gaze at those sublime but rugged heights. I knew that there must be on those summits many things which to me would be new and full of interest. No, I seldom went out of my tent without casting a worshipful look into the south. Indeed the picture in the distance was beautiful to look upon in clear weather. We were informed that directly south of us in that range was the highest mountain east of the Mississippi, and geological reports etc., which Chaplain Foote picked up about town increased our desire to make a trip, but it could not safely be done by the few who were anxious to go, so it is all well.

The immediate vicinity of Jonesboro was dry in botanical novelties to me. I only took two plants, *Carices nigro-marginata*, and *umbellata* (sedges), from its precincts. I will enclose a few of them in this although they may not be new species.

On our advance from Huntsville we stopped half a day at Chattanooga, Tennessee, and during that time I with several others climbed to the top of Lookout Mountain. *Climbed,* I say, and indeed climbing it was, and the most severe half day's journey I have recently made. It seems to me almost incredible that an army stationed on its summit should ever have been defeated by a force coming from below, yet it was done successfully by General Hooker's army. On the top of this height I found a few flowers which I have never seen elsewhere, and these are a sufficient compensation for my labors of that afternoon, severe as they were.

The lichen enclosed is from Lookout Mountain. There were large ones from this species but dry weather had reduced them to such a fragile condition that I could only preserve small pieces. They grew on the sides of the rocks at the summit.

You express the same sentiment with regard to the death of Mr. Lincoln which is felt by us here. We received the terrible tidings while at Jonesboro, but were slow to believe such a horrible report. But it is no great wonder that we who are but the merest children in knowledge and foresight in comparison with the omnipotent, should sometimes be shocked and almost disheartened by the manifestations of His unerring hand, for His course sometimes seems to be directly contrary to the one which our best wisdom and most perfect skill would mark out.

He moves in a mysterious way
His wonders to perform
He plants his footsteps on the Sea
And rides upon the storm.

And dark and mysterious though they seem to our perceptions, yet true faith leads us to submit all our ways to Him, and then we have peace and assurance that we will be well in the end.

Even now we begin to believe that Mr. Johnson is going to be just the man to decide the fate of the arch traitors, and we think that our beloved Mr. Lincoln would have been too lenient towards them, and by and by we may see that it was well that God called him who was our choice anyway.

The memory of Lincoln is immortal in the minds of our people; he has fulfilled his great mission with faithfulness and has laid aside the mortal and put on the immortality. The great responsibilities that were resting on him as President of the U. S. in the day of the nation's peril, is removed and he rests, we hope, with God, for he confided in that name in which to trust is to gain the victory of death and to secure to the soul of fallen man a life that is eternal.

With best wishes to you and your family, I subscribe myself, with love

Your friend,

EDWARD LEE GREENE.

Write soon and address
3rd Brig., 3rd Div., 4th A. C.,
Nashville, Tenn.

Monticello, Ill., May 1, 1867.

Mr. T. Kumlien,
Albion, Wis.
My dear Sir:

It is now a little more than three weeks since I visited you, and this morning I propose to have a brief chat upon familiar subjects, trusting the proposal will be met with pleasure on your part. And in the first place I am well and, after having employed a couple of weeks in visiting relatives, etc., I am at last settled down to labors and studies for the season. I find myself very happily situated and have a fine prospect of making many new acquaintances in Flora's domain, and some among the Mollusca for I believe there are a goodly number of species of land snails in the low timber along the river and descriptions of them have commenced in the April No. of the Naturalist.

The weather here seems to continue rather cool and farmers complain of a late spring, neverless the woods are becoming green and there are a good many flowers already.

On the 13th of last month I found in the woods growing and flowering with Hepatica, the little trillium which I enclose. What species it is I am unable to determine. It is far too large for anything which Mr. Wood describes except *T. nivale* (dwarf white or snow). In *nivale* according to that author the peduncle is very short and erect, whereas in this they are comparatively long and specimens which I took on the 15th had the flowers completely deflected beneath the leaves. Besides, a damp northern forest hill side is not the place for *T. nivale* whose habitat is "dry fields."

Among the plants I have already taken are the following of interest perhaps to you namely, *Isopyrum biternatum*, *Cardanine rhomboidea* (bittert cress) *Claytonia virginica* (spring beauty) *Trillium recurvatum* (wake robin) and *Mertensia virginica* (Virginia cowslip, bluebells), the latter a plant of most exquisite beauty whose equal in this respect I do not expect to find during the season. It is going to be difficult to preserve, but with proper care doubtless I shall save a few nice ones. *Claytonia* (spring beauty) is abundant in all soil and extremely variable, yet I think there is but one species here.

Five weeks hence I shall probably have my leisure hours all occupied if I attempt to preserve half a dozen representatives of each new species that I shall find. Would that you could be here to "help yourself" and to add to my joy. Tell my dear friend Ludwig I wish he were here to collect eggs and skins in Illinois and be my companion in my rambles. I have seen not a few birds already which I have not noticed in Wisconsin. A red-headed woodpecker is quite frequent which is entirely different from our Wisconsin red-head, being rather larger and I think much handsomer. The marking of its body are, I should think, a kind of gray and white and the top of its head as light as scarlet. A pair of cardinal grosbeaks are building a nest near my boarding place. If I can keep the mischievous boys away you shall have their eggs. Wild turkeys I have frequently met in the woods. They breed here I am told, but they say it is time for them to commence hatching. I have sought for their nests but thus far in vain. Birds large and small are abundant here, and I am told that the larger waders, swimmers, etc., have their breeding places in those parts of the prairie that are yet unsettled and where the great grasses and sedges still flourish in all their glory in a virgin soil. The nearest locality of this description begins some twenty or thirty miles east of us. I almost peruade myself that I shall go there in spite of the difficulties and spend a day. This country is very different in its appearance from Wisconsin prairies; here are merely little patches of a few hundred acres, but they spread out before the eye just like the broad expanse of old ocean itself. Timber grows only along the rivers. The land is generally low, rocks and hills scarce, and the climate rather unhealthful.

If I have health, I remain here a year for teachers get very liberal pay. I shall have no difficulty to get from fifty to eighty dollars a month during next fall and winter after which I intend to go a little way north to some good school. At Bloomington in this state and only some thirty miles north, is located the state university. I am going to see it sometime during the season if practicable. The state society of Natural History has here its museum. According to the published transactions this society bids fair to be something. Indeed it already is. It is exclusively a society of Natural History and the only one in the state. It is possible that I shall attend school there, though hardly probable for I have no doubt the school is better at Evanston near Chicago. But no more at present. With love to your family and requesting the favor of a letter soon as convenient I am yours in bonds of friendship.

EDWARD L. GREENE.

Address—
Monticello, Pratt Co., Ill.

Monticello, Ill., Tuesday, Nov. 9, 1869.

Very dear Friend!

"Tis a time for memory and for tears." One of the most genial and refined spirits which it has been my happiness to know has passed away from earth. The startling and painful news reached me a few days in advance of your letter by one from my mother. And you thought of me, so did I of you. The dear old man had few except his kindred who appreciated him as we did, and how sadly it rests upon my heart that neither my mother nor yourself knew of his *sickness* even until he was gone. Had it been possible I would have been with him in his last moments. It seems hard to think that they who were so much attached to him as I know you and my mother were should not have seen him after the spring of life began so rapidly to fail, yet the fault, if there be any, is not yours. Yes, I shall miss him. I have during my absence from home enjoyed an occasional letter from him, and now this time I sent him my first letter on the very day he died.

When I shall return to Albion, be it sooner or later, I shall then miss him more. Instead of a cordial welcome to his pleasant home, I shall find his grave. And a gloomy place will be the spot where his hand reared flowers. This sad event will admonish us anew that the friendships of earth are only transient (or rather that their constant enjoyment is a thing not to be expected) for "amicitia vera est sempitema," and we cherish fondly the memory of friends departed and hope to enjoy their society again "when the dream of life is fled."

I now realize as I never did before, the fact that if I should live to old age, I must see yet many dear friends pass away from my side "into the silent land" and it seems that my old age will on that very account be sadder and more devoted to sacred themes than was my youth. No, it seems not strange that the aged are usually less mirthful than the young. I have never lost a parent nor a brother. I have not known the pangs of parting for time with the very near and dear, and the news of Mr. Clark's death reveals to me that I loved him as I have not loved many whose remains I have seen consigned to the grave. I could scarcely control my feelings sufficiently to perform my school duties on the day I heard of it. Seeing that these dear ties of earth are so slenderly united, let us cherish them the more fondly while they last, and when broken we shall await in sweeter anticipation the day that shall in God's infinite love and mercy unite us again to the dear ones gone before.

Monticello, Ill., Sunday, March 27, 1870.

Prof. Thure Kumlien,
Busseyville, Wis.
My very dear Friend:

You are kind indeed to give me two letters for one. I had thought to wait until I should have obtained a view of the "everlasting hills" and get some new things to tell you before I would answer yours which I received some weeks since. But you write again in the meantime and ask for a line before I start. Well here you shall have it and very welcome you are to it. I had for a week or two been looking for a letter from Ludwig. I am sorry to hear of his affliction.

Well, I feel as if I were about done with this country for the present. One week more to teach and then I am off. I hope to start from Decatur for St. Louis one week from tomorrow, which will be the 4th day of April. From St. Louis I go to Kansas City, thence by the

Kansas Pacific railway directly to Denver, Colorado. The road is now finished to within a few miles of Denver.

I am, as you suggest, going to take a good supply of paper. I have reflected on the probable scarcity of that article at some points I may reach. For Ludwig I have already packed some little vials of alcohol for insects, and I will not fail to do my best for a few skins for you.

We have spring now pretty well settled in this latitude. Spring wheat and barley were sown last week quite extensively. But as it rained a good deal yesterday, work of this kind will be delayed for a day or two. Birds of spring are plenty. Three weeks ago or more, I guess four, we had the bluebird and the robin. Blackbirds and I cannot mention all I have heard within two weeks, and a week ago I saw a pewee, and they have been singing every morning during the past week. Ducks and geese in almost endless droves have been flying, and some cranes. But the waders and swimmers are not so plentiful as they will be in a couple of weeks. On Wednesday last I saw a fine flock of sandhill cranes sailing high in the upper azure. They were led by two beautiful specimens of the white plumaged species. I have seen several small flocks of the latter, but they seem fond of the society of their brethern of the gray coats.

In a couple of weeks more I shall probably find flowers. Even now the hazel bushes are in flower.

I think some of stopping on my way, for a few days, at the coal mining region a few miles east of St. Louis. I have formed the acquaintance of several genial persons who live there, and they urge me to call on them. It will be an interesting place especially for a geologist, which I am not however. But I may nevertheless see interesting trees and possibly yet a few flowers, for the spring is two weeks earlier there than here. In East St. Louis lives Mrs. Hinchcliff whom you have seen, but I have not, yet on account of the dear memory of her late venerable father, I will try to find her.

Tell Ludwig I will perhaps send him a letter from some point on my way and to you I will write as soon as I arrive in Colorado.

Now perhaps another thousand miles or more may separate us, ere we hear from each other again, but we cannot join hands and say farewell. Think of me sometimes. Go and see my mother's flowers for yourself and *me* when you pass that way. I would gladly have seen my Wisconsin home and friends before I started on my long journey, but it would take time and money, and not least, the sadness of the parting again, would almost neutralize the joy of meeting.

With much love to you all, I bid you for a time adieu.

EDWARD L. GREENE.

Denver, Colorado, Probably about April 15, 1870.

My dear Friend:

Here I am at my writing table, but I almost believe I had better be out getting flowers; but it is a dry, hot afternoon so I will wait until towards night. There are not yet many flowers. I have however, already a collection of fifteen numbers and I know of several more I might add today. Every tramp I make I find new and unexpected ones. There seems to be no spring in this country. It is either winter or summer. During the two weeks (nearly) that I have been here, we have had many dry, hot days, and one severe snow storm! No April showers, no bursting leaf buds, no springing green grass, but yet flowers and seeds.

The country seems almost destitute of deciduous trees. There are several species of poplars, but I have seen no others. Not an oak, hickory, or anything of the kind, but oh what forests of pine and fir! I have already been some twenty miles into the mountains, but I did not stay. It is too soon. However I found an old Wisconsin favorite on the lower range. It was our *Bulsatilla* (pasque flower) with flowers a trifle more deeply colored, but in no other way differing from the same plant of Wisconsin. With it grew also *Ranunculus*, but not *R. glaberrimus* as described in N. A. Flora. Last week I sent my mother a plant which I wish you may see when it flowers.

I should never like this country for a home. I love too well the pleasant May and June of the North. The season of green grass and above all of blooming fruit trees which I suppose can never be experienced here. The winters are so changeable from cold to extremely hot days that fruit trees do not succeed at all and the summers are so long and dry that I suppose the beautiful European grasses must also fail. The grasses of the plains only grow in tufts and patches and never carpet the hot soil, yet there are lots and lots of flowers among them. I see them now springing up everywhere and different kinds on every bluff and knoll. (A few lines torn off here) are too apt to bring frosts even in midsummer for corn to be safe. Yet the few who have during the past five years given themselves to farming are now immensely rich, so high have been the prices of farm products in the extensive mining districts of the mountains. Garden vegetables are plentiful along the streams where they can be irrigated, grow very luxuriantly, and to sizes almost incredible.

Pork is not raised for want of corn, but beef is easily fattened on the grasses of the plains where the dried pasturage of winter is almost as good as it is in summer. I will not write more at present. Write to me and by the time I get your letter I will have ready for you a package of Rocky Mountain plants. Now this I know will be an inducement. Direct to Denver, Colo. I am as ever with love to you all,

EDWARD L. GREENE.

Dudley's Ranch, May 12, 1870.

My dear friend Kumlien!

Your letter is *very, very welcome*. It does me much good to hear from home and friends. I am not altogether gone crazy over the world of beauty and novelty that now surrounds me. I am among strangers of the human kind and do really at times feel that I could appreciate as I never did before the society of those whom I have long known. But this is only a natural sequence and is both pleasant and unpleasant. This afternoon I took five letters from the office and it almost made me cry! One from my mother and two from brothers. What a blessed thing our mail system is!

Well, as you would suppose, I am having really a glorious time; all the flowers I can possibly manage now. Most of the flowers are on the plains, but I am in the mountains every week, and there by much fatiguing effort climbing cliffs and descending precipices, by hanging with my shoe toes in the crevices and my hands to pine and juniper limbs, I get a good many fine things. It is almost too early for flowers to be plentiful in the mountains. The higher and more distant ranges are yet white with snow to their very bases.

These mountains were very appropriately named Rocky. They seem built of nothing else. On their summits and often on their terraced sides are large forests of Coniferae. It is in these forests chiefly that I must look for flowers. I want to get up to the limit of trees sometime in the summer if possible.

Now in a few days I am going to send you a small package of flowers. You will find them chiefly leguminous plants and especially *Astragali* (milk vetches). Of this genus I have already specimens of half a dozen species, and I know of as many more that are hardly yet in flower. They are, unlike our eastern ones, very handsome. The little low silky one is a mountaineer. *A. sincolencus* of Gray, or *Phaca sericea* of Nuttall grows in pretty spreading masses a foot broad on bleak and barren summits of high hills or mountains. Prof. Gray sent me a work of his entitled, "A Review of North American Species of Astraglus and Oxytropis." In this work *Phaca* is reduced to *Astragulus*. It seems that although in the time of Linneaus the genera were both well founded, yet the discovery of very many new species through which the two run together, has broken down the wall that separated them. I shall not be able to give you the names of many of them until I have the fruits, for Gray has made almost too exclusive use of the fruits in his descriptions and classifications. One hundred and twelve species in N. A. of *Astragulus*, that are tolerably well known either by flower or fruit or both. *Oxytropis* is less known. On my last week's tour in the mountains I found two beautiful ones of which I will send you representations. You ask me if I am going to stay all the season. I answer I intend to remain at least two seasons. But it is uncertain. I can probably do better in the winter at teaching here than I could in the states. It costs considerable to come here I found and I want to get the good of the trip by seeing and getting all I can. I want by all means to get as far south as Santa Fe before I return, so that I can have a good deal to talk about and a good deal to show you when I get back.

It is true as you perhaps know, that we have some prospects of Indian difficulties here, but I hope not to be driven home by a war. Indeed I think I will not. I have seen a great many of the Indians of the Utah tribe already, and they are said to be at peace and friendly to the whites, but I do not like their faces, and by no means would I like to commit myself to their mercies. We hear of miners and others in remote and unsettled parts, being disturbed and driven from their work by them. There is a difficulty starting about the right of the whites to occupy North Park, a section of this territory. This may end in something serious, but I hope not.

May 13, 1870.

The weather continues very warm and dry. I have just been out a little way only upon the plains, and have recorded the collection of specimens of a *Nasturtium* (water cress), a *Senecio* (groundsel, ragwort, squaw-weed) and a *Chenopodium* (goosefoot, pigweed), the latter in fruit. All new to me. But I saw more beautiful things than those. I found a true *Cereus* in flower, *C. veridiflorus* with greenish yellow, very fragrant flowers. It is just beginning to bloom. Also a most beautiful *Castilleia* (painted cup) not described in any of my books. It is low, like *C. sessiliflora,* which also grows here as in Wisconsin, but is larger or rather stouter, with extremely large and showy bracts, deeper red than any of *C. coccinea* I ever saw. It would be an acquisition to flower gardens well worthy of a conspicuous place. I will secure seeds without fail. I found also what must be a night flowering *Enothera* (evening primrose); the *very* large delicate pink flowers were withered somewhat and collapsed, stem low and branching, leaves small, a lovely plant. Perhaps you may raise it from seed if I get any, though it is evidently a biennial and might not stand a Wisconsin winter.

Well, I do wish you were here to help me, or to get the birds and mammals, reptiles and insects. If I stay during the winter I will see what I can do in the line of bird skins for you, though I shall perhaps never become an expert in that art. I see a great many hawks more than I ever noticed elsewhere. There is in the mountains a very handsome bird called magpie, which I would like you to see. It is black and white with a very long tail.

A mile from where I board is a republic of prairie dogs. I have passed through it several times and seen and heard the little fellows, but no rattlesnakes nor owls. A Pennsylvanian in the neighborhood, who has an Utah squaw for a wife, with a progeny of twelve black haired, dark skinned hybrids, has near his house a colony of forty tame prairie dogs. It consists of the progeny of a tame pair, with perhaps the original ones also.

No buffalo here, but any quantity of their horns are to be found on the plains, and also the prodigious large antlers of the elk, still telling the passer-by what beasts once roamed these wide spreading plains.

Well, if this letter reaches you some Saturday night and you stay at home the following Sunday, I presume you will have time to read most of this, but now I will close. Tell friend Ludwig I have a bottle of alcohol into which I drop a beetle now and then and when it is full

I have thought I would send it to him. But am going to stop and put no more in until I hear from him.

So you still have a Scandinavian who is a parasite of Cornwall. It is a pity. He may perhaps get satisfaction yet however as others have done before him. I am sorry indeed to hear of Rasmus' and Karina's misfortune. (Mr. and Mrs. Rasmus B. Anderson). They have now an angel to invite them heavenward; one gone before who stayed with them long enough to have become very dear no doubt. I have for some time been expecting a letter from Rasmus. Now adieu! With love to you all I remain as always,

Your sincere friend,

EDWARD GREENE.
Denver, Col. Ter.

Please don't fail to write again soon. Your letter was *very* interesting.

Saturday Evening, June 25, 1870.

My good Friend:

Many thanks for your letter, but it reached me rather late, only yesterday. The trouble is that in the vicinity of Denver are two Edward Greens and two E. L. Greens, three in all, who may get my letters, two of whom have no business with them. Yours had evidently been opened and carried for a long time in some one's pocket and then returned to the P. O. What shall I do to prevent this annoyance? Surely I cannot invent.

Well, I am very glad to congratulate you on the pleasure you have enjoyed in meeting with so excellent a gentleman from the old country. Had I dreamed of such a thing I suppose I would have sent three times as many flowers as I did. You of course did the very best thing, to give him the little things I sent, and I shall almost be beside myself at the sight of plants from the Dovrefjild.

If I thought I could come home within a year, I would have you keep them for me. But you can send them in a package I suppose with perfect safety for my papers and such things are never troubled by others, and indeed I do not think I have lost any letters, but I have repeatedly taken from the office letters to Ed. or Mrs. (?) E. L. Green that evidently were not mine.

So you found *Linnaea borealis* (twin flower) in the little marsh! So did I six or eight years ago, but could never find it the second time though I often sought for it. I have found it abundant in several localities in the mountains, always at a great altitude. Two or three times since I wrote I have been away into the mountains and have seen more than I can begin to tell you. I will get another package which shall contain some of the fine things. On the 13th inst. I went some twenty miles up the mountains by the road, but stopped when I had arrived at the altitude where *Populus tremuloides* (American aspen) was just putting forth tender leaves. I was yet twenty miles from the snowy range. I am told that I need not go there until the middle of July at the earliest. How strange it still seems to me to look over into the west on these hot midsummer days and see the distant mountains streaked or capped with snow. Some of my finest things now are plants too large to send in a mail package. I will mention a few of them descriptively. First upon the list is *Aquilegia* (columbine) a mountain plant with very large flowers, blue and white. It even leaves our cultived ones all in the shade. About four species of *Oenothera* (evening primrose) are magnificent. A white one (accidental) has flowers at least three inches broad with a fragrance that resembles that of *Nymphaea odorata* (sweet-scented water lily) but is more delicate. It grows in the mountains only and flowers in the night. I almost went crazy over it when I found it one morning before the sun was shining in the valley. One very like it has golden yellow flowers as large but less fragrant. The corollas of these beautiful things are very delicate in that one is obliged to dry them without removing them from the paper until they are perfectly dry. I have splendid specimens of some of them. None of them is at all coarse looking like our *O. biennis,* but are low or stemless, with flowers purplish or white mostly. I have six species of *Pentstemon* (beard tongue), but I don't know whether you are acquainted with the genus or not. There were two in central Illinois, but I believe none in Wisconsin. They are splendid. You will see from the specimens how *Dodecatheon meadia* (shooting star) grows in the Rocky Mountains. I thought it another species when I first found it growing in dense patches among wet moss on the rocks, so small and so dark. I find that it varies in size in different localities. The dark color of the flowers however is unvarying here. None pink or white. Nor have I seen it more than half as large as the largest Wisconsin ones. I suppose the authorities are correct in not giving it the specific rank. This little mountain species of *Senecio* (groundsel) I know will interest you and the mountain *Erigeron* (fleabane) too. One day this week I gathered *Opuntia* (prickly pear, Indian fig) and a desperate time I had of it. Nuttall's name, *Cactus ferox,* is very appropriate for all the varieties of *Opuntia missouriensis.* It is a detestable job for the hands for the articuli have to be sliced with a knife or they would never dry and the spines are all sizes and all over the plant. Three species of this genus are all I find, though *O. rafinesquii* and *O. missouriensis* have each many well marked varieties. The little *O. fragilis* is hateful. One cannot come near it without the spines poking into one and the fragile joint breaking off and clinging to one. What think you of Mr. *Astragalus pictus?* Isn't it queer? In fruit it is beautiful! Pads large, inflated and richly spotted. Its foliage too is so strange for an *Astragalus.* I will send you seeds of this and other *Astragalus* soon. I do not know how many I have of them now, and I found more in the high mountains not in flower.

Sunday, June 26, 1870.

I have just got *Potentilla effusa* (cinquefoil), a beautiful thing with pinnate leaves white with soft tomentum and with diffuse leafless stems, very slender. The plains are now in places blue with lupines. I see only two species, *L. pusillus* and *L. polyphyllus*. The latter is tall and very showy.

When I wrote you last I told you I had not seen the little owl that associates with the prairie dog. I have since seen two pairs of them. I will try to get a skin or two when I am done with the flowers, that is in the fall or winter.

I have put in another specimen of *Saxifraga nivalis* that you may have one to compare with your Dovrefjild *Saxifraga*. The other plants I send are different from those I sent before.

With your letter I received one from Stephen T. Olney of Providence, R. I. requesting specimens of Colorado Carices (sedges). That gentleman is writing a monograph of the N. American species of *Carex*. This is not a great country for Carices, however I am sending him a package of fourteen species that I have gathered up mostly in the mountains. On the range in their season I shall probably get a good many more.

Now if you could be here to go with me in two or three more weeks up to the edges of eternal snowbanks! The distance is not less than fifty miles and most of the way through the mountains. What a time we would have! I shall probably go alone, but there is a good wagon road as far as Georgetown, which is not more than eight miles from the snow, or rather from the summit of the snowy range. Well, you may perhaps hear in my next what I get if I am successful in making the trip.

In looking over the package you will find several things not named, because my botanical library is incomplete and very many of my descriptions are by Nuttall, who is not very clear in his diagnoses. *Rubus nutkanus* (salmon berry) is a beautiful bush with flowers as large as roses. I am going to send you and mother seeds of it. Belonging exclusively to the mountains I think it would thrive in Wisconsin. Write very soon. If you send my little Norwegian mountaineers, direct just as you have done and I am confident I shall be able to get them all right: otherwise I would wait until I should see you, but that may be a long time.

With warm regards and best wishes to you all, I remain as ever,

Your friend,

Ed. L. Greene.

Golden City, Nov. 21, 1870.

My dear Friend:

For the last three or four months I have been thinking, while waiting to hear from you, that if you did not care enough about hearing from me to answer my letters, I would not write. However as it has now been half a year since I received the last word, I have thought it possible that you may have written and that the letter may have been lost. Though I am not certain that I have ever yet failed to receive any letter which has been sent me. The person in Denver who bears my name, and who has on one or two occasions taken letters which belonged to me, I am now very well acquainted with, so that if he should get them I am quite certain he would not retain them. And what in the world is Ludwig doing that he does not write.

I have many interesting things to say to you, but I only write this to let you know that for all these months, I have been awaiting in vain for a reply to my last.

I remain and ever will, Your sincere friend,

ED. L. GREENE,
Golden City, C. T.

Jarvis Hall, July 22, 1871.

My dear friend Kumlien:

You are the same dilatory correspondent, are you not? Nevertheless I overlook it again and take up my pen to talk with you for a few moments.

A few days ago I returned from a ten days' trip in the higher mountains where you can imagine what a time I had. Now it is to me a surprising fact that the most beautiful wild flowers I ever saw in my life, I have seen growing right in the vicinity of eternal snows! I am going to enclose a little *Primula* (primrose) (I know not what species), of which a large patch was growing less than ten feet from the edge of a deep snow drift which covered not less than ten acres of ground. The flower has quite changed its color. It was most exquisite. The little delicate *Saxafraga* grew also at the edge of the snow. I got four other Saxifrages besides this one, all of which are new to me and those of which I find described in the Flora Lapponica, I think.

I have all the spring been applying myself so closely to divinity studies, that until within a few weeks I have quite neglected botany. During the past week I have received a note from Prof. Gray, and one from Dr. Engelman, both enquiring what has become of me. Dr. E. tells me that he has two of my new species of *Opuntia* growing from both seed and from joints I have sent. And, by the way, I am reminded that I have not yet sent you *O. greenei.* I will do so now in a day or two. There is a fine specimen growing on our college grounds. I noticed it full of fruit this morning.

I expect a visit in a few days from Wm. M. Canby, a distinguished botanist from Delaware. At least Mr. Olney tells me he has directed him to call on me on his way to California. I hope he will come of course.

On the day before yesterday someone knocked at my door, and as my roommate opened the door, I instantly recognized the voice of Charles Clausen asking for "Mr. Green." I have not been so surprised in a long time. I was of course delighted. I learned from him at once that his father was in Denver and that they were both to start from Denver home again the next day. I returned with Charley to Denver and tried to persuade the Reverend gentleman to remain longer, but in vain. I like the Rev. Mr. C. very much though my acquaintance with him was very short. He tells me that it is quite possible that he will emigrate to this country in the spring. Now just sell out that little place of yours, get a wagon and team and come along, and let us enjoy each other's society among these mountains for a few years before we die.

Tell friend Ludwig that if he doesn't write to me pretty soon I shall give him over entirely. My love to all you and yours. Please write.

EDWARD L. GREENE.

Denver, Colo., Sept. 25, 1871.

My dear Friend:

I never expect to hear from you again, but you shall know that I think of you. I change my home this week and go to the town of Greeley in this territory to have charge of the congregation there during the winter. If you can write, address me there.

As ever,

ED. L. G.

Love to you all.

Greeley, Col., Easter Even., 1872.

Thure Kumlien Esq.
Busseyville, Wis.

My dear friend:

Certainly you have at last given me a treat indeed. I confess I have, during the past week, indulged a faint hope that I should hear from you this spring. I had actually been looking for this letter for several days. Now it is all right and you may look out by and by for some flowers. First of all I must tell you that two weeks ago I received a letter from Prof. Gray enclosing his photograph, and a promise that he will be my guest for a few days next summer Des volente! Don't you think I was almost crazy with delight when that letter came? You know that since I have been in Colorado I have had many letters from him, and have sent him specimens of all my collections, and he has named in my honor, at least two of my species.

I am sorry that my alpines are now all gone. Gray has himself set several other botanists after me, who have begged me out of almost everything, but they give me fine exchanges.

The little one flowered primrose is *Primula integrifolia* too. The dear little beauty grew within three feet of the edge of an eternal snowbank. But oh, if you could see the *Primula parryi* Gray, I think you would at least throw up your hat and scream with delight. It is the most magnificant wild flower I ever saw, and I believe I am the third who has ever collected it. I preserved only three specimens, for it is a large and rather succulent plant, and I was on foot when I found it, and had to collect specimens as large as I could each, of 125 species that I had never seen before; consequently, save of the smallest, I only got two or three specimens each. *P. parryi* is a foot high with leaves somewhat like those of *Dodecatheon* with you, only twice as large and handsomer green. The stem bears a cluster of flowers each ¾ of an inch in diameter, of the most beautiful purple or perhaps mauve, and are fragrant. And then where it grows! In the edges, among the stones of those crystal mountain streams, in deep fir tree shades, about a mile or a half mile from snow. The scenery of its locality is fit for the home of such a wonderful flower. If I get to its locality another year (and my good church wardens have already given me a permit to take my vacation during Prof. Gray's sojourn) I will not come back without a specimen for you.

It seems to me now while I write that by all means, if possible, you should come to Colorado and come to stay and collect here the rest of your life. But you know better than I no doubt. If you could manage to sell out and move, it would be a grand thing I believe. But I will not suggest any more on this point. It is really singular that you should have found those orchids as you relate. I have laughed heartily over your amusing account of it.

Goodyera menziesii (rattlesnake plantain) and *Corallorrhiza multiflora* (coral root) (both orchids) (a large one) I found last summer growing together in the mountains near Golden City.

I should think your plant is *C. odontorhiza* Nutt. according to my last edition of Gray. He says it is "rare northward" that is in Michigan, etc.

How nice a little affair that *Primula scotica* is. I am right glad to see it.

Visiting a parishioner of mine the other day I obtained a very pretty specimen of *Erica vulgaris* L., or *Calluna vulgaris* Salish. (Neather). It had been sent from England in a letter. I shall be right happy if you ever get around to send me a package of Norwegian plants. I guess I told you of my 59 species of Swedish Carices received from Olney.

And so you fancy you see me with a wife—a mistaken fancy I assure you. I am not married, and to me it seems now quite probable that I never shall be. I shall soon be twenty nine years of age, and am not engaged nor in love. It seems with my preaching and botanizing to have enough to keep me busy and happy. Happy as any mortal ought to expect to be. I am getting that old bachelor notion that a wife would only be in the way. So I guess I am bound to know the whole of single blessedness. I at least do not ask to be happier in the world than I have been since I was ordained a minister. I rejoice that we have spring. I saw the first wild flowers, *Berberis aquifolium* (barberry) three weeks ago. Where is Ludwig that I never hear from him? I think he is a remarkable fellow indeed, to let me go two whole years without one word. Give my love to your dear ones, and remember me ever as your friend.

EDWARD.

Greeley, Col., Sept. 26, 1872.

My dear Friend:

Your letter of Aug. 30th was duly received, and I am much obliged to you for being so prompt.

Yes, I had the honor of meeting the great Prof. Gray; and certainly he is one of the most delightful men I ever saw. I went to the mountains ninety miles away to Empire City near Gray's Peak, a week before he came that I might not fail to meet him. However, he stopped in Greeley, or rather just got off the train and enquired for me. He thought he might meet me in Denver, where he found a letter from me telling him where to meet me. I met him at Empire City on Saturday evening Aug. 10th, just at dark. Was presented to him by the celebrated Dr. Parry, of fame as a collector in Mexico, California and Colorado. Dr. Parry had been here some months and is yet in the mountains collecting seeds. I expect a visit from him in about two weeks. Well, on Monday the 12th Dr. Gray, Dr. Parry, and myself, with some other unscientific gentlemen, made the trip to the top of Parry's Peak, and made our first tramp together, collecting no end of fine things; were caught for some twenty minutes in a fearful snowstorm, accompanied with lightning that made our hair snap, and stand on end with electricity at every flash. The snow covered up all our botanizing for about half an hour, and then it disappeared almost momentarily, when the sun came out. The storm was very unpleasant, for we were far above the limit of trees, and had no protection.

Wednesday and Thursday were occupied in making the ascent and descent of Gray's Peak, the highest mountain this side of the Parks. That was a tiresome job, and yet well worth the trouble and fatigue. For the last two or three miles toward the top no vegetation whatever, but a few rock growing lichens met our eye, and it was nothing but climb over sharp and often coarse rocks. And you may understand that after twelve or thirteen thousand feet altitude is reached, it requires some muscular exertion to get breath. Mt. Gray is 14,245 feet high, and the view from the top is probably one of the most magnificent which this world affords. I can never describe it and will not try. Prof. Gray stayed in Empire and thereabouts just one week only, and then we bade him farewell. His wife, a very amiable lady, was with us, even to the top of the Peak. She is a botanist too.

Dr. Parry is one of those quiet, diffident men who know a great deal more than one would think. Gray regards him as a great botanist though he has never published anything.

Well, I have seen more than Prof. Gray, for last week I was down to Denver for a few days; at the depot one morning I noticed on the platform waiting for the train a very aged gentleman, whom I took to be a botanist when I saw among his hand baggage an unmistakable bundle of specimens in press. I stepped up and begged his pardon for asking his name. Judge of my delight when he replied, "I am called

Dr. Torrey!" Yes, sure enough here I stood in the presence of and shaking hands with the venerable teacher, and associate in labors of Prof. Gray. He was on his way to the mountains to visit Gray's Peak. I was not able to go with him though he urged me. I had never corresponded with him but he knew me and we were as familiar friends from the moment I gave him my name. *Carex torreyi* (sedge discovered by Dr. Torrey) had been one of the finest of my finds in Colorado, and I was the second who had found it in the U. S., Dr. Torrey having been the first. He found it in Pennysyvania in a few specimens many, many years ago where nobody else has since been able to detect it. I find and collect a hundred specimens in Colorado.

Well, I rode with Dr. Torrey to the end of the railway, seventeen miles that morning, and have not seen him since, and it is not likely that I ever shall again. He is some seventy-five years old, though in apparent good health of body and vigor of mind. I missed him on his way back, though I watched for him. But I am very glad to have seen him and conversed with him for an hour. He of course will not long be numbered with the living botanists, and in my old age, if I live, I shall be glad to be able to say that I saw him.

Gray is sixty two, though he seems fifteen years younger. A handsome man and one of the most delightfully pleasant men you ever saw. Always smiling and always talking, and his speech affected by an occasional slight stammering. It was very, very interesting to see him pick up something which he himself had first described and named, and ask, "Parry" or "Green," "What is this" and then after a closer examination, "Oh, it is -------- -------- isn't it? Oh, yes, I never saw it growing before." Yes, I have certainly had a rich delight in seeing these three great botanists, and now I wish I could see you and tell you more than I have time to write. Please let me hear from you again. Have I sent you a specimen of *Museniam Greenei*, an umbellifer discovered by me last year? My love to you and your family,

Ever,

E. L. Greene.

Vallejo, Cal., April 30, 1874.

My dear Friend:

Your long and interesting letter is received. I am not going to answer it just now, but I send you herewith the last four numbers of the Naturalist, knowing that it may be a gratification to you to read some of their contents. One of them contains the notice of Ludwig's bird. There are also a number of articles on botany—an unusual number. Those from Prof. Farlow on the visits to European historical fields will carry you back to your old home—at least in fancy. The papers on Wyoming botany, by my dear friend Parry, and those from my own pen, will also I trust interest you.

When you and Ludwig have read the magazines you can return them. I have no recollection at all of having sent you any Appleton's Journals, nor do I remember to have read what you refer to. Some one else I think, has done you that favor. With love to all, I am as ever,

Your affectionate friend,

EDWARD LEE GREENE.

(This letter is to Ludwig Kumlien, son of his friend and teacher, Thure Kumlien.)

Vallejo, Cal., Sept. 3, 1874.

My dear Ludwig:

It almost seems that I have an old friend risen from the dead, this getting a letter from you after I guess almost five years of silence. Well, I need not waste time and paper to assure you of how glad I am to hear from you, and also to have a photograph of your face. You have grown big and devised a little beard, and that is all the difference I am able to detect in your looks, comparing of course the photograph with the picture that is in my memory. I am greatly obliged for so long a list of news. I have not heard so much about Albion and vicinity I think, since I left there. Now that all our family are away I have absolutely no correspondence with any resident in that section, except the very *occasional* letters I get from Monsieur, your father.

I hope now you will not fail to do better by me, now that you have succeeded so well in this lately renewed effort.

What a time I have had since I saw you, ranging over the wonderful plains of Wyoming and northern Colorado, and the cactus deserts, even away down to the borders of New Mexico; and climbing about the perpetual snows of the Rocky Mountains, up to the altitude of 14,245 feet; and now at last have been six months on the Pacific coast. I have naturally added somewhat to my knowledge of botany and have a splendid collection of western plants; and have been so fortunate as to discover a few new species, and have rediscovered a number of long lost ones, that had been found only by such early botanists as Nuttall, James, etc. I have had a fine time, also have worked my way into the pulpit so as to have no trouble about the wherewithal to pay my expenses. But my new parish at Vallejo is too much for me. I have a large congregation and good salary, but with all that, so much pastorial work, that my scientific studies are interfered with not a little. I have also the prospects of being even called to a large San Francisco church on three thousand dollars a year, to which if I go, I fear I shall turn out either a poor shepherd for so large a flock or else give up more still of my favorite studies. However, I am thankful for so much happiness and success as seems to attend me in several ways.

My people in Colorado are doing well indeed. I wish you could see our Rocky Mountain home. It would delight you. I am heartily glad to hear of your father's prospects of becoming able to devote himself to his favorite pursuits, with a fair remuneration. I hope after a few years more, fewer than have elapsed since we met, that we shall all meet again. I *long* now to see old Wisconsin and botanize again along Lake Koshkonong and thereabouts. It would be as good as a new field to me, almost, not to mention the bliss of the companionship of a few old friends I could name. Write very soon. Give my love to all your people and believe me as ever yours,

E. L. G.

I will send that stick before long.

(This letter also is for the son Ludwig.)

Georgetown, Colo., Nov. 22, 1875.

My dear Ludwig:

I shall no doubt surprise you again by writing still from Georgetown, Colorado. But you may learn after awhile never more to be surprised at any of my unaccountable doings. On the very eve of my departure for California, I came to a disagreement with the Bishop of Northern California, to whose jurisdiction I was going, and the result was, I said to him, "I will not go." So here I am.

How did it come to pass that you heard I was to visit Wisconsin this fall? Perhaps the wife of my brother Manzel who visited Albion, spoke of something of the kind for I did in the summer encourage my brother who lives in Minnesota to think I would visit him before ever I should return to the far Pacific coast. But there will, as it appears, be time for that yet. However, I must confess since you wrote me last I have been, for a few weeks, comparativly near you. I was in central Illinois for four weeks and now have just returned. When I determined not to go to California, I said to myself, "I will take a trip somewhere anyway." I wanted to see Dr. Engelman in St. Louis, and my relatives in central Illinois, besides many other friends that I made there while teaching in 1867, '68 and '69. You will ask me I know, why I did not come on to Wisconsin. The reasons are several. For one important reason I give this, I did not feel like seeing Albion, my old home, etc., so soon after that deplorable event of my mother's death. I should be sad all the time I knew if I went. For another reason, I could not wish to go there without several weeks to devote to calling on the different people whom I should wish to see. Moreover if I should have gone to Wisconsin at all there could have been no sort of an excuse for my not going on to visit my brother in southern Minnesota. I had not at my disposal the two or three months I should have needed for visiting all three of the vicinities mentioned, so I determined to wait and visit Wisconsin and Minnesota perhaps another year.

I am very glad to hear of you at the University. Give my love to Prof. Anderson and tell him the last book I read was his "Norse Mythology" with which I was greatly pleased. I have no letter from your father for now these many months. I trust he is well. How much I would love to see you all.

I am wintering this year in a very interesting, if not pleasant place. Georgetown is built in a little narrow valley at 8,400 ft. above the sea. The mountains on the east side of town rise very abruptly 2,300 ft. higher, and on the west 3,000 ft. higher, while to the south Leavenworth Mountain summit is about 1,500 ft. above the town. The sun rises at this season at half past nine, passes behind Leavenworth Mountain at 12; reappears a little after one, and disappears for the day shortly after two. We now have about a foot of snow on the ground, but it is not extremely cold. In fact the thermometer rarely falls below zero at Georgetown at any time during the winter. It is what many would call a most dreary place in which to spend a winter, but I doubt not I shall pass the days very pleasantly with my books and my herbarium, and a great many specimens of things new to me, to be studied and put away in their place. I have more than three thousand specimens of foreign plants on hand now which I have never looked at, and many from the new Northwest. I ought to be very happy. I wish you could visit me in Colorado before long. Can't you do it? At least write to me often and believe me,

Your faithful friend,

EDWARD L. GREENE.

Berkley, Cal., Jan. 9, 1885.

My dear Friend:

I did not wait for your letter. The printer was in a hurry, so I gave in what you will see by the proof sheets enclosed. You will also see that the plant has been handled by Asa Gray. But it was a handling loosely and carelessly, just as he has handled many a score of western genera and species which he knew naught about, saw in poor specimens. You will perceive by my written character that, by both flower and fruit, it is wide of *Ranunculus*. I am sorry to say it is a rarity. I never saw it growing, but I hope I shall some day. We have in the Herb. Cal. Acad. three specimens only! I think I will give you one of these. For the rest you must wait until I or some friend of mine shall collect more. Its nearest locality is more than two hundred miles from where I am. I trust the bulletin containing this and many more of my doings will be ready for distribution soon and a complete one shall be sent you. I have not the time to write more tonight.

Yours as always,

EDW. L. GREENE.

(The following letter was written to O. A. Linder, Chicago, Ill., who was preparing a paper on the "Life of Thure Kumlien.")

National Museum, Washington, D. C., Nov. 7, 1908.

My dear Sir:

I take pleasure in enclosing to you, as a loan, the last letter I ever had from Thure Kumlien. It is perfectly characteristic from beginning to end; shows the perfection of his beautiful handwriting at the age of sixty-seven, and the autograph at the end, just as he always wrote it.

I think you will see from this letter that, with Kumlien, I was not a companion in age, but rather, a boy of whom he was very fond and helped many years before this letter. The fact is he and my father were born in the autumn of the same year, 1819. Very curiously, also, Kumlien's oldest child (early deceased) was born on the same day that I was. I am now sixty-five, but then if Kumlien and my father had now been alive, each would have been in his ninetieth year.

His opening of this fine letter in the use of an adage in Swedish explains itself in this wise. At fifteen years of age I spoke Norwegian and English with equal readiness, on all matters appeartaining to work and business. To Norwegians I was a marvel on this account.

At Kumlien's house, when once some of Mrs. Kumlien's relatives newly from Sweden were guests, and knew no English, I talked with them in Norwegian, they answering in Swedish; and Mr. Kumlien took a new pride in me from the fact that certain Swedish words, differing considerably from their Norwegian equivalents, *I* had no difficulty in understanding, while *they* often failed to get the meaning of certain Norwegian words of mine, though my pronunciation was always said to be so faultless.

You must not locate Mr. K. as one of any Scandinavian colony. His house was four or five miles away from Koshkonong Prairie, and in the woods near, and in view of Koshkonong Lake. No Scandinavians were anywhere near him. When in my boyhood, I first knew him, all his neighborhood was occupied by Yorkshire English, small farmers. All his older children were baptized by Anglican, that is, Protestant-Episcopalian ministers. Only the youngest Frithiof, was christened by a Norwegian Lutheran minister.

I am sure you will be pleased with this piece of his handwriting, and kindly be very careful not to lose it, and return it when it has served your purpose.

Very truly yours,

EDWARD L. GREENE.

In the letter from Berkeley, California, dated January 9, 1885, Mr. Greene, who was then Professor of Botany at the University of California, wrote his old friend Mr. Kumlien that he had just named in his honor *Kumlienia hystricula.* In his paper describing this flower in the California Academy of Sciences, Professor Greene says, "I gladly dedicate this very characteristic plant of our Sierras to Prof. Thure Ludwig Kumlien, A. M., formerly Professor of Natural History at Albion, Wisconsin, a learned and zealous naturalist, and my first instructor in the science of botany."

After the death of Mr. Kumlien in 1888, Mr. Greene wrote and published in his Pittonia, a beautiful eulogy in honor of his friend. In closing he says, "but these small tokens, like our worded tributes, are all inadequate to speak the praise, or worthily perpetuate the memory of a man so pure, so simple, so noble and so well beloved."

When Edward Lee Greene died on November 10, 1914, the world lost not only a valued botanist, but also a man of sterling quaiities of character, a man who set high value on friendship; he was a man who loved the out of doors, not only the well trodden paths, but the mountain peaks and the cactus deserts, and a man who loved truth for its own sake.

Fort Atkinson, Wisconsin.

MICROCHEMICAL TESTS ON THE CELL WALLS OF CERTAIN FUNGI. CELLULOSE AND CHITIN

E. W. HOPKINS

The similarity of the life histories of the lower fungi and many of the lower algae would seem to warrant the expectation that the composition of their cell walls would have something in common. The analogies of structure and function observed in the Phycomycetes and the green algae indicate what is apparently a direct relationship between these forms. The Ascomycetes occupy a more doubtful position, appearing to be related to the red algae, or to the green algae through the intermediary of the Phycomycetes. The Basidiomycetes, however, show little or no relationship to either the lower fungi or to the algae. It would be expected that the Basidiomycetes would show a greater deviation from the algae in composition than would any other class of fungi.

Earlier workers believed that the cell walls of fungi were made up of a modification of cellulose which was called "fungocellulose." Richter (1881) made cellulose tests on *Agaricus campestris, Daedalea quercina, Polyporus fomentarius,* and Mucors. Chlor-zinc iodide and iodine-sulfuric acid tests were made on sections which had been previously treated with alkali. Positive cellulose reactions were obtained with all except the Mucors, which gave no certain result. The author concluded that fungocellulose was true cellulose.

De Bary (1887) was of a different opinion. The so-called "fungo-cellulose" differed from true cellulose in that it was insoluble in Schweitzer's reagent, and did not give the color with iodine which is characteristic of cellulose. True cellulose reactions, however, were given by the Saprolegnieae, *Protomyces macrosporus,* Peronosporeae, young Mucors, and the cells of the resting perithecium of *Penicillium glaucum.* Similar results are reported by Winterstein (1893) who removed fats and proteins from fungus material, and found that the residue was insoluble in Schweitzer's reagent. He concluded that it was a cellulose differing from that in tissues of higher plants. Gilson (1893) was unable to obtain crystalline cellulose from *Mucor vulgaris, Thamnidium vulgare,* and *Agaricus campestris,* while he succeeded easily with plant tissue. He believed that fungus tissue did not contain cellulose.

Perhaps the greatest variety of materials was tested by van Wisselingh (1898). This author reports the presence of chitin in Myxomycetes, Peronosporales, Saprolegniales, Chitridiales, Entomophtharales, Mucolares, and in almost all of the higher fungi. Reactions for both chitin and cellulose were obtained with Myxomycetes and Phycomycetes, although the reactions were given by different portions of the hyphae. Chitin seemed to be confined to certain portions rather than to the entire cell wall. Wester (1909) prepared chitosan salts from *Mucor muceda, Xylaria hypoxylon, Peziza aurantia,* and *Xylaria polymorpha.* Chitin is reported by Vouk (1915) as being present in the following fungi: a Mucor, *Helvella crispa, Peziza aurantia, Xylaria polymorpha, Plicaria cervina, Agaricus fusipes, Amanitopsis plumbea, Boletus sanguinus,* a Clitocybe, *Cortinarius obtusus, Hygrophorus conicus, Mutinus caninus, Psalliota campestris,* and *Russula aeruginosa.* Extensive studies of chitosan salts were made by Brunswik (1921) These salts were prepared from *Lepiota procera, Pholiota squarrosa, Lycoperdon caulatum,* and an Aspergillus. These preparations were identical with chitosan salts of animal origin. Gwynne–Vaughan and Barnes (1927) made the statement that the cell wall of fungi is usually of cellulose, or of a special variety known as fungal cellulose.

Thomas (1928) using several species of Fusaria, extracted the proteins from the hyphae, and made an ammoniacal copper sulfate extraction of the residue. This reagent dissolved a material which appeared to be cellulose, giving cellulose color reactions, and hydrolyzing to reducing sugars. The hyphae were still intact, and gave tests for chitin.

The variations in results given by the above investigators may be attributed in part to the different methods used. One heated the material with glycerine to remove the cell contents, while another let the sections stand in concentrated alkali to remove the protein constituents of the cells. Various adaptations of the tests for chitin and cellulose were used. With the many variable factors concerned, it is surprising that these workers did not report even more conflicting results.

The methods used in our work were those recommended by the most widely accepted authorities on micro-technique. Three tests for cellulose were employed, and one test for chitin.

Cellulose Tests.

1. Iodine-potassium iodide-sulfuric acid test. The sections were saturated with the iodine-potassium iodide reagent, the slide tilted, and the excess solution removed by placing a blotter at the lower edge of the drop. The blotter did not come in contact with the section, and any cellulose fibers adhering to the slide could not been confused with material in the section because of their difference in appearance. Cellulose gives a very deep blue color when treated with these reagents. Molisch (1923).

2. Iodine-potassium iodide-phosphoric acid test. This test was performed in the same way as the one above, except that it was necessary to heat the sections since the acid used was weaker than that in the first test, and consequently did not penetrate the cell wall as readily. Cellulose gives a deep violet with this treatment. Zimmermann (1901).

3. Chlor-zinc iodide test. This is one of the standard tests for cellulose, giving a dark violet-blue color with that compound. Molisch (1923).

Chitin Test.

Van Wisselingh (1898) sealed sections of material in glass tubes with concentrated potassium hydroxide solution. These sealed tubes were then heated in an oil bath to 180° C., cooled, the tubes broken, and the sections removed. The alkali was removed by washing with 90 per cent alcohol. After washing the section thoroughly with alcohol, it was placed on a slide, saturated with an iodine-potassium iodide reagent the excess of this solution removed as before by blotting, and dilute sulfuric acid added. Chitin gives a violet color when treated in this way.

A much simpler method is given in detail by Vouk (1915) and recommended by Eckerson. This method consists in boiling the material for 20-30 minutes in a saturated aqueous solution of potassium hydroxide in a beaker and washing the material with 90 per cent alcohol. The remaining steps are not explicitly stated, but since this method was based on that of van Wisselingh, it is very probable that the remainder of the procedure was left unchanged, i. e., the sections were treated with iodine-potassium iodide reagent and sulfuric acid. Vouk first states that his preparations give the chitosan reaction "nach bekannten Weise mit Jodjodkalium." This statement does not exclude the use of sulfuric acid from the test. Further, this author states, "Nach dem Auswaschen in 90 p. ct. alkohol trat die Reaktion mit Jodjodkalium immer prompt ein." It seems doubtful that the use of sulfuric acid is indicated by this statement. Miss Eckerson, in adapting the method, does not state that sulfuric acid should be used. When the test as described by this author is applied to flies' bodies, no violet color appears, but it *does* appear when sulfuric acid is added. Other sources give tests for chitosan with iodine-potassium iodide reagents, and no sulfuric acid, but these tests all gave negative results when applied to parts of flies' bodies. The test for chitin was made by the procedure recommended by Vouk and Eckerson except that sulfuric acid was used to convert the chitosan to a material which gave a violet color with iodine-potassium iodide.

The number of materials to be tested for chitin made it impossible to boil them all together with alkali in a beaker. In order to keep them separated, and to easily distinguish the different materials tested, each was placed in an agglutination tube. These tubes were inserted for about half their length through the meshes of a screen of the proper size to hold them firmly. This screen, with the tubes held firmly in place, was then suspended in an oil bath. The samples in the tubes were covered with saturated KOH, the oil bath heated to 130° C, and this temperature was maintained for 25 minutes. The sections were then fished out of the tubes, washed with 90 per cent alcohol, placed on a slide, and iodine-potassium iodide and sulfuric acid added.

Four cultures grown in the laboratory were tested daily, and tests were also made on material collected at random. The laboratory cultures were grown in Petri dishes as giant colonies on malt agar (3 per cent malt extract, 1.5 per cent agar.) Sections of the colony were removed daily, and the duplicate tests made upon it. The agar did not interfere materially with the tests, and in no case gave a color which would be mistaken for a positive test. The cultures grown on agar, and tested systematically were: *Mucor rouxii, Aspergillus fumigatus, Thraustotheca clavata,* and *Achlya imperfecta.*

In table 1 are given the results of the tests on *Mucor rouxii.* In the first 3 tests when the culture was 2, 4, and 5 days old respectively, all the tests were negative, although a pale violet color was given with chlor-zinc iodide, and on the last day a questionable chitin test was obtained. When the culture was 7 days old, colors which were very similar to these given by cellulose appeared with all of the cellulose test reagents, and a positive chitin test was obtained. On the 8th day, so much of the material had been removed from the first Petri dish that it was necessary to take material from another plate. This gave negative cellulose tests and a positive chitin test. Though both were started at the same time, their development may be very different, due to the vigor of the culture, the size of the inoculum, or a lack of uniformity of favorable conditions. The lack of concord between the results of different workers using the same fungus may well be due to such factors. On the 9th day, the chitin test was negative, while the cellulose tests were questionable, a color being obtained which was similar to that given by cellulose. On the 10th day, the cellulose tests, except the chlor-zinc iodide test, were positive, and the chitin test was negative. An old culture of *Mucor rouxii* which happened to be available was also tested. The cellulose tests except the chlor-zinc iodide test were positive, and the chitin test positive.

Aspergillus fumigatus gave somewhat different results. (Table 2.) At no time was a positive cellulose test obtained, although a pale violet color was observed with chlor-zinc iodide from the 7th to the 10th day. The chitin test was questionable on the 4th and 5th day, but positive on the 7th and 8th day, negative on the 9th, and positive again on the 10th. On the 12th day, all tests were negative.

Thraustotheca clavata (table 3) and *Achlya imperfecta* (table 4) at all times gave identical tests. The cellulose tests were all strongly positive throughout, the color becoming very intense as the cultures increased in age. The chitin tests were all negative, although in the older cultures, a blue coloration appeared which, however, was quite different from the color given by chitin.

The results of the tests on the higher fungi are recorded in table 5. No form gave a positive cellulose test. Chitin tests were given by some, and not by others. In the cases where the chitin test was most positive, the violet coloration seemed to be confined to the cuticle, never extending far into the tissues.

Perhaps the greatest discrepancy occurs in table 1 in the cellulose tests. It is probable that the second culture used had not developed as far as the first one. In the chitin tests given in tables 1 and 2, there is a most discouraging lack of consistency. This may be due to several factors. The test in itself is not easily made. The sections used, though as small as possible, may nevertheless have been too large to enable the reagents to thoroughly penetrate the cell walls. The hyphae were always very much matted after boiling in alkali, and it was not possible to separate them. This made the test very difficult to observe, and may account for the lack of consistency of the results. The other two cultures used, *Thraustotheca clavata* and *Achlya imperfecta,* had such large and rigid hyphae that the tests were very easily observed.

In all of the tests made there is always a question regarding interfering substances. The cellulose tests were made in such a way that other substances giving a blue color with iodine would not be mistaken for cellulose. This was accomplished by saturating the section with iodine-potassium iodide reagent, and examining under the microscope before sulfuric acid was added. No blue color was observed in any case before addition of sulfuric acid.

SUMMARY

Twenty-two species of fungi distributed through the Oomycetes, Zygomycetes, and Basidiomycetes, were tested for chitin and cellulose. The chitin test used was that of Vouk. Three cellulose tests were made: iodine-potassium iodide-sulfuric acid test, iodine-potassium iodide-phosphoric acid test, and the chlor-zinc iodide test.

Four fungi were grown on malt agar and tested daily. These were *Thraustotheca clavata, Achlya imperfecta, Mucor rouxii,* and *Aspergillus fumigatus.* The remaining fungi were tested as they were collected.

The lower fungi, Saprolegniales, gave strong tests for cellulose, one of the Mucorales gave tests for both cellulose and chitin at different ages, and the higher fungi gave negative tests for cellulose, though several gave chitin reactions.

It seems very likely that if these tests were made on a greater variety of forms, or systematic tests of cultured forms extended over a greater period of time, the results would permit more definite conclusions than are possible from this work.

The writer wishes to express his sincere gratitude to Dr. E. M. Gilbert of the Department of Botany under whose direction the work was done, and to Dr. E. B. Fred of the Department of Agricultural Bacteriology for helpful criticisms.

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TABLE 1. *Cellulose and chitin tests on Mucor rouxii.*

Tests	Number of days							
	2	4	5	7	8	9	10	45
Cellulose.								
1. Iodine–potassium iodide–sulfuric acid	—	—	—	+ (?)	—	+ (?)	+	+
2. Iodine–potassium iodide–phosphoric acid	—	—	—	+ (?)	—	+ (?)	+	+
3. Chlor–zinc iodide	Pale violet	Pale violet	Pale violet	+ (?)	—	Pale violet	—	—
Chitin	—	—	+ (?)	+	+	—	—	+

TABLE 2. *Cellulose and chitin tests on Aspergillus fumigatus.*

Tests	Number of days						
	4	5	7	8	9	10	12
Cellulose.							
1. Iodine–potassium iodide–sulfuric acid	—	—	—	—	—	—	—
2. Iodine–potassium iodide—phosphoric acid	—	—	—	—	—	—	—
3. Chlor–zinc iodide	—	—	Very pale violet	Very pale violet	Very pale violet	Pale violet	—
Chitin	+ (?)	+ (?)	+	+	—	+	—

TABLE 3. *Cellulose and chitin tests on Thraustotheca clavata.*

Tests	Number of Days					
	4	5	7	8	9	10
Cellulose.						
1. Iodine–potassium iodide–sulfuric acid	+	+	++	++	++	++
2. Iodine–potassium iodide–phosphoric acid	+	+	++	++	++	++
3. Chlor–zinc iodide	+	+	++	++	++	++
Chitin	—	—	—	—	—	—

TABLE 4. *Cellulose and chitin tests on Achlya imperfecta.*

Tests	Number of Days					
	4	5	7	8	9	10
Cellulose.						
1. Iodine–potassium iodide–sulfuric acid	+	+	++	++	++	++
2. Iodine–potassium iodide–phosphoric acid	+	+	++	++	++	++
3. Chlor–zinc iodide	+	+	++	++	++	++
Chitin	—	—	—	—	—	—

TABLE 5. *Cellulose and chitin tests on higher fungi.*

Fungus tested	Cellulose. Iodine-potassium iodide sulfuric acid	Cellulose. Iodine-potassium iodide phosphoric acid	Cellulose. chlor-zinc iodide	Chitin
Xylaria polymorpha	−	−	−	−
Cordyceps militaris	−	−	−	−
Laboulbenia formicarium	−	−	−	+
Peziza bodia	−	−	−	−
Fomes applanatus	−	−	−	+
Fomes fomentarius	−	−	−	+
Polyporus betulinus	−	−	−	+
Polystictus hirsutus	−	−	−	+
Boletus felleus	−	−	−	−
Strobilomyces strobilaceous	−	−	−	−
Cantharellus cinnibarinus	−	−	−	−
Russula subdepallens	−	−	Slight violet on gills	+
Collybia platyphylla	−	−	−	+
Lactarius piperatus	−	−	−	−
Lactarius fuliginosus	−	−	−	−
Chamaeota sphaerospora	−	−	−	++
Pluteus nana	−	−	−	+
Amanita bisporiger	−	−	−	+

THE HEPATICAE OF WISCONSIN

GEORGE HALL CONKLIN

INTRODUCTION

This report of the Hepaticae of Wisconsin is based upon a re-examination of the specimens in the herbaria of the University of Wisconsin and the New York Botanical Garden, and a study of the specimens collected in Wisconsin. To this has been added the collections of the writer made during the past 20 years in Douglas, Bayfield, Ashland, and Iron counties. This report also includes an examination of the collections of that indefatigable collector, L. S. Cheney of Barron, Wis., who in the years from 1893 to 1897 made a botanical survey along the upper Wisconsin River valley from State Line, Vilas Co., to Kilbourn, Sauk Co., also along the Montreal River, the White River, and the south shore of Lake Superior from Montreal River, Iron Co., to Superior, Douglas Co.

Only a few of the specimen numbers of the Cheney collections of 1893 were placed in the University Herbarium. The work of identification was done by Dr. L. M. Underwood. After Dr. Underwood's death his herbarium and unidentified collections were purchased by the New York Botanical Garden. In 1911 Miss C. C. Haynes named the material, and a duplicate set was given to the University of Wisconsin. An opportunity was given to verify this material. In 1926 Mr. Cheney gave to the botanical department of the University of Wisconsin the later collections and remaining duplicates. These have been named and included in this report and returned to the University Herbarium. Of more recent collections this report also includes the following stations and collectors:

Dr. C. E. Allen	Devils Lake, Sauk Co.	1915, 1916, 1917
	Solon Springs, Douglas Co.	1915.
	Arena, Iowa Co.	1922,
	Glen Haven, Grant Co.	1924.
	Sawyer Co.	1926.
	Green Lake, Green Lake Co.	1926.
	Lake Wapogasset and Bear Trap Lake, Polk Co.	1927.
Daisy S. Howe	Osceola, Polk Co.	1901.
C. D. Baker	St. Croix Falls, Polk Co.	1897.

N. C. Fassett and L. R. Wilson St. Croix Falls, Polk Co., and Mellen, Ashland Co., 1927.

J. M. Holzinger Along Mississippi and St. Croix Rivers, Polk, St. Croix, Buffalo, and Trempealeau Counties, 1890 to 1906.

An examination has been made of all the known and available material collected in the state, both named and unnamed. It was thought that such a critical study of the old herbarium material, together with the unreported collections of more recent dates would be of value to future students in the study of plant distribution. Early virgin conditions of forests, waters, and surface soils are fast changing in many counties of the state. Owing to the denudation of forests, the drying up of lakes and swamps, and the drying and erosion of waterways, the bryophytes have been especially effected. In many places they are fast dying out. The species here recorded of early dates have in many instances wholly disappeared from the stations recorded.

History

(1) The earliest known records of Hepaticae collected in Wisconsin are found in the University of Wisconsin Herbarium. These are a few specimens from the herbarium of I. A. Lapham, with the following data:

Reboulia hemisphaerica (L.) Raddi (labeled *Fimbriaria tenella*). Dells of Wisconsin River (Sauk Co.), Aug., 1858.

Bazzania trilobata (L.) S. F. Gray (labeled *Mastigobryum trilobatum*). Penokee (Ashland Co.), Sept., 1858.

Porella platyphylla (L.) Lindb. (labeled *Madotheca* platyphylla). Penokee Iron Range (Ashland Co.). No date given.

Porella platyphylla (L.) Lindb. Blue Mounds (Iowa Co.), June 1, 1860.

Ricca fluitans L. (no. 43), ex. coll. I. J. Hale, 1861.

Several other specimens with dates unrecorded are from the herbarium of I. A. Lapham and were probably collected about this decade.

(2) There is one specimen of *Ptilidium pulcherrimum* (listed as *P. ciliare,* no collector given), from Milwaukee, Milwaukee Co., with the date of 1862.

(3) J. M. Holzinger collected *Anthroceros laevis* L. August 18, 1890, at Marshland, Buffalo Co.

(4) In 1891 and 1892 L. S. Cheney and R. H. True collected in Dane Co., about Madison; in Fayette, Lafayette Co., and Lake Mills, Jefferson Co. It was during these years that Professor Cheney, at that time connected with the University botanical department, made his first trip to the north, collecting from Fond du Lac to Grand Portage, Minn., along the north shore of Lake Superior. His trip extended along the International Border from Grand Portage to Ely, Minn., ending the trip at Barron, Wis. The collected hepatics were reported in the Transactions of the Wisconsin Academy (2). Most of the region covered in this botanical survey was in Minnesota. A few collections however, were made near Fond du Lac, Minn., on the Wisconsin side of the St. Louis River in Douglas Co., and when the trip ended, some collecting was done about Barron, Wis. This was in 1891, and 15 species from Wisconsin were recorded and correctly named.

(5) In 1893 the American Association for the Advancement of Science met at Madison, and a collecting trip was made to the Dells of the Wisconsin River. A few species were found and bear the label of L. M. Underwood, collector.

(6) Professor Cheney, beginning in 1893, began a survey of the upper Wisconsin River from State Line, Vilas Co., to Wausau, Marathon Co. He continued during the succeeding years, 1894 to 1897, to explore the Wisconsin River valley and the northern water shed. Collections were made from Drummond, Bayfield Co., down the White River; along the Montreal River in Iron Co. to Lake Superior; along the Lake Superior shore from Montreal River to

Ashland, Bayfield, Oak and La Presque Islands, Cornucopia, Herbster and Superior.

What would one not give now and what hardships not endure for the sight of those virgin forests, moss-covered ledges, forest-edged waterfalls, cascades, and rapids, which he found along the northern Wisconsin rivers!

His collections were extensive, both of flowering plants and of bryophytes, and are now the most valuable of any made in the state. In 1895 the collection of the year 1893 was partially reported and published (3). He listed 33 species. The University herbarium contained only a few of the published specimen numbers. The numbered packets in the herbarium which contain additional species or in which the name is changed upon re-examination are as follows:

No. 998. *Aneura latifrons* is now known as *Riccardia latifrons* Lindb., and contains also *Sphenolobus exsectaeformis* (Breidl.) Steph.

No. 1284. Aneura species? is *Riccardia palmata* (Hedw.) Carruth.

No. 1548. is *Pellia neesiana* (Gottsche) Limpr.

No. 59. *Jungermannia schraderi* is *Odontoschisma denudatum* (Mart.) Dumort., and *Lophozia porphyroleuca* (Nees) Schiffn.

No. 2864. *Jungermannia schraderi* is *J. lanceolata* L.

Nos. 638, 1247. *Jungermannia excisa* is *Lophozia incisa* (Schrad.) Dumort.

No. 628. *Jungermannia exsecta* is *Sphenolobus exsectaeformis* (Breidl.) Steph.

Nos. 1032, 1980. *Chiloscyphus polyanthos* is *C. fragilis* (Roth) Schiffn.

No. 1992. *Chiloscyphus polyanthos* is *C. rivularis* (Schrad.) Loeske.

Nos. 948, 951, 952. *Kantia trichomanis* is *Calypogeia neesiana* (Massal. & Carrest.) K. Mull.

No. 463. *Cephalozia multiflora* is *C. connivens* (Dicks.) Lindb.

No. 1254. *Cephalozia multiflora* contains also *C. pleniceps* (Aust.) Lindb.

No. 1263. *Cephalozia multiflora* contains also *Lophozia porphyroleuca* (Nees) Schiffn. and *Sphenolobus hellerianus* (Nees) Steph.

No. 1331. *Cephalozia multiflora* contains also *C. connivens* (Dicks.) Lindb. and *C. pleniceps* (Aust.) Lindb.

Nos. 15, 20, 25, 27, 48, 89, 35, 561, 1560, 1757, 1871, 2116, 2192, 2194. All *Ptilidium pulcherrium.* (Web.) Hampe.

No. 2127. *Ptilidium ciliare* as listed.

No. 1325, 1327. *Porella platyphylla* is *P. platyphylloidea* (Schwein.) Lindb.
No. 1026. *Radula complanata* is *R. obconica* Sullivant.
No. 2365. *Frullania asagrayana* contains also *F. brittoniae* Evans.

(7) In the report of Cheney and True on the flora of Madison and vicinity (2), fifteen liverworts were listed. A re-examination of this material gives a few additions and changes of nomenclature, as follows:

No. 188. *Frullania Asagrayana* contains also *F. brittoniae* Evans.
No. 883. *Ptilidium ciliare* contains also *P. pulcherrimum* (Web.) Hampe.
No. 884. *Lophocolea bidentata* is *L. heterophylla* (Schrad.) Dumort.
No. 888. *Preissia commutata is* now known as *P. quadrata* (Scop.) Nees.
No. 890. *Asterella hemisphaerica* is now known as *Reboulia hemisphaerica* (L.) Raddi.
No. 899. *Grimaldia barbifrons* is now known as *G. fragrans* (Balb.) Corda.

(8) In August, 1902, Prof. C. E. Allen collected extensively on two of the Apostle Islands, Madaline and LaPresque, Ashland Co. This collection was reported in August 1904 (4). 21 species were listed. A re-examination of this material added 9 species and the following corrections:

No. 4. *Pellia endaevifolia is P. epiphylla* (*L.*) Corda.
No. 10. *Chiloscyphyus polyanthos* is *C. pallescens* (Ehrh.) Dumort.
No. 17. *Ptilidium ciliare* is *P. pulcherrimum* (Web.) Hampe.
No. 19. *Scapania undulata* is *S. subalpina* (Nees) Dumort.

Additional species found in the material were: *Lophozia kaurini* (Limpr.) Steph., *L. porphyroleuca* (Nees) Schiffn. *Sphenolobus exsectaeformis* (Breidl.) Steph., *Plagiochila asplenioides* (L.) Dumort, *Cephalozia catenulata* (Huben.) Spruce, *Jungermannia pumila* With., *J. sphaerocarpa* Hook., *Nardia hyalina* (Lyell) Carringt., *Odontoschisma denudatum* (Mart.) Dumort.

(9) In 1914 G. H. Conklin published a preliminary report (6). The area covered in this report included Douglas and Bayfield Counties in Wisconsin, and Carlton, St. Louis, and Lake Counties in Minnesota. 83 species were listed, 67 of which were found in Wisconsin. Since that

publication 31 additional species have been found by the writer in Douglas, Bayfield, Ashland, and Iron Counties, namely:

Frullania asagrayana Mont., *F. oakesiana* Aust., *Lejeunea cavifolia* (Ehrh.) Lindb., *Lophozia bicrenata* (Schmid.) Dumort., *L. excisa* (Dicks.) Dumort., *L. attenuata* (Mart.) Dumort., *L. alpestris* (Schleich.) Evans, *L. badensis* (Gottsche) Schiffn., *Jungermannia sphaerocarpa* Hook., *J. schiffneri* (Loitles.) Evans, *Scapania undulata* (L.) Dumort., *S. paludicola* Loeske & K. Mull., *S. cuspiduligera* (Nees) K. Mull., *Chiloscyphus fragilis* (Roth) Schiffn., *Cephaloziella byssacea* (Roth) Warnst., *C. elachista* (Jack) Schiffn., *C. bifida* (Schreb.) Schiffn., *C. hampeana* (Nees) Schiffn., *Odontoschisma denudatum* (Mart.) Dumort., *O. macounii* (Aust.) Underw., *Diplophyllum apiculatum* (Evans) Steph., *D. gymnostomophilum* Kaal., *Nardia hyalina* (Lyell) Carringt., *Jungermannia pumila* var. *rivularis* With., *Pallavicinia flotowiana* (Nees) Lindb. *Ricciocarpus natans* (L.) Corda, *Sphenolobus scitulus* (Tayl.) Steph., *Reboulia hemisphaerica* (L.) Raddi, *Porella platyphylloidea* (Schwein.) Lindb., *L. ventricosa* (Dicks.) Dumort., *Sphenolobus hellerianus* (Nees) Steph.

The writer can now report 102 species from Wisconsin in the counties bordering Lake Superior. The following species also have been collected by him in the Minnesota counties of Carlton, St. Louis, Lake, and Cook which have not yet been found in Wisconsin.

Lophozia longidens (Lindb.) Macoun, *L. marchica* (Nees) Steph., *L. grandiretis* (Lindb.) Schiffn., *L. rutheana* (*Limpr.*) M. A. Howe, *Calypogeia suecica* (Arn. & Perss.) K. Mull., *Sphenolobus minutus* (Crantz.) Steph., *Marsupella emarginata* (Ehrh.) Dumort., *Asterella Ludwigii* (Schwaegr.) Underw., *Scapania umbrosa* (Schrad.) Dumort.

The Hepaticae of North America are represented in Wisconsin by 44 genera and 116 species. This is a fairly good number considering that only 33 counties in the state have been explored. It will be seen that this review of the known specimens found in the state adds 37 species which have not before been correctly reported, namely:

Metzgeria conjugata, Pallavicinia flotowiana, Chiloscyphus fragilis, Jungermannia cordifolia, J. schiffneri, J. sphaerocarpa, J. rivularis, Lophozia alpestris, L. attenuata, L. badensis, L. bicrenata, L. excisa, L. guttulata, Diplophyllum apiculatum, D. gymnostomophilum, Nardia hyalina, N. crenulata, Sphenolobus scitulus, Cephaloziella bifida, C. byssacea, C. elachista, C. hampeana, Odontoschisma denudatum, O. macounii, Scapania cuspiduligera, S. dentata, S. paludicola, S. undulata, Frullania inflata, F. oakesiana, Anthoceros punctatus, A. macounii, Riccia sorocarpa, R. beyrichiana, Grimaldia pilosa, G. rupestris, Frullania riparia.

It will be seen from the state-county map (fig. 1) that only in a few counties has any systematic collecting been done. The number of species collected in each county is indicated by numerals. The most promising counties for new species not as yet visited are these of Door, the counties along the Mississippi in the unglaciated areas, and the Red Cliff Indian Reservation in Bayfield Co. I know of no regions more promising for new species or for the extension of range of known species than these areas. This survey of the Hepaticae of Wisconsin, which has been deferred a long time, was made possible when L. S. Cheney in 1926 released to the University herbarium the bulk of the specimens collected in northern Wisconsin in the years 1893 to 1897. As stated, a large number of these specimens were sent Dr. L. M. Underwood, some of which were reported in the Transactions of the Academy in 1894. After Dr. Underwood's death, the New York Botanical Garden purchased his herbarium and duplicates. After a lapse of these many years, these three groups of collected specimens have again come together and are deposited in the University of Wisconsin Herbarium.

Grateful acknowledgement is here given to Dr. A. W. Evans of Yale University, Miss Annie Lorenz of Hartford, Conn., and Miss Caroline C. Haynes of Highland, New Jersey, for their assistance during the past fifteen years in verifying and naming difficult species, and to Dr. C. E. Allen and Dr. J. J. Davis of the University of Wisconsin for their courtesy permitting a free examination of the materials in the University Herbarium.

The names of the collectors and herbaria which have been abbreviated are:

L. S. Cheney of Barron, Wis., Cheney.
C. E. Allen of Madison, Wis., Allen.
G. H. Conklin of Superior, Wis., Conklin.
University of Wisconsin, U.
New York Botanical Garden, NY.
University of Minnesota, UM.
Sullivant Moss Society Hepatic Herbarium, SMS.
L. R. Wilson of Superior, Wis., Wilson.
N. C. Fassett of Madison, Wis., Fassett.
J. M. Holzinger of Winona, Minn., H.

In the catalog the specimens following a named collector are of his collection and the stations following a named county are from that county.

MARCHANTIALES

RICCIECEAE

1. *Riccia fluitans* L. Herb. I. A. Lapham, 1861, (no station recorded), ex. coll. *F. J. Hale* 43 (U); Dells Wisconsin River, Sauk Co., July 7, 1883, *E. G. Knight* (NY); Barron, Barron Co., Aug. 13, 1891, *Cheney* 62 (U); Newbold, Oneida Co., July 10, 1893, 1584 (U); Stevens Point, Portage Co., July 4, 1894, 3490 (U); Webster, Burnett Co., 1894, 3441 (U); Drummond, Bayfield Co., June 22, 1896, 4040 (U); Superior, Douglas Co., July 26, 1897, 1713 (U); same location, Aug. 3, 1907, *Conklin* 267, 2365 (SMS).

2. *Riccia arvensis* Aust. Madison, Dane Co., Oct. 10, 1891, *Cheney* (*U*); Webster, Burnett Co., 1894, 3441 p. p. (U); Madison, Dane Co., Oct. 10, 1892, *Cheney* & *True* (U); Arena, Iowa Co., Sept. 2, 1922, *Allen* (U). Near Afton, Rock Co., Oct. 26, 1928, *Cheney,* 12871 (U), det. M. A. Howe.

(Two Ricciae appear in the collections which can not be named. Both specimens are without spores and immature.)

3. *Riccia beyrichiana* Hampe. Bagley, Grant Co., June 5, 1927, *Cheney,* 12205 (U), det. M. A. Howe.

4. *Riccia sorocarpa* Bisch. Glen Haven, Grant Co., June 6, 1927, *Cheney* 12245 (U), det. M. A. Howe.

5. *Ricciocarpus natans* (L.) Corda. Black Earth, Dane Co., (no date recorded), *Hale* (U); Madison, Dane Co., Feb. 20, 1892, *Cheney* "D" (U); Orienta, Bayfield Co., July 15, 1897, 7350 (U); Billings Park, Superior, Douglas Co., Oct. 1, 1924, *Wilson,* 2358 (SMS); Lodi, Columbia Co., Oct. 9, 1926, (SMS); Oconomowoc, Waukesha Co., June 27, 1925, (SMS); St. Croix Falls, Polk Co., Sept. 4, 1927, *Fassett & Wilson* (U).

REBOULIACEAE

1. *Grimaldia fragrans* (Balb.) Corda. Madison, Dane Co., May 1891, *Cheney & True* (U); same location, June 1, 1891, *Cheney* (U); Potosi, Grant Co., May 19, 1926, 11295 (U); same location, June 1, 1926, 11407 (U); Glen Haven, Grant Co., May 4, 1926, 12136 (U); Lake Wingra, Madison, Dane Co., Aug. 23, 1893, *L. M. Underwood* (NY); St. Croix Falls, Polk Co., *C. D. Baker,* 20 (NY); Glen Haven, Grant Co., April 12, 1921, *Allen* 3 (U); Bradford Tp. Rock Co., Aug. 7, 1928, *Cheney* 12760 (SMS.U), det. C. C. Haynes; Hanover, Aug. 17, 1928, *Cheney* 12793 (SMS.U).

2. *Grimaldia pilosa* (Hornem.) Lindb. Glen Haven, Grant Co., May 14, 1927, *Cheney* 12160, 12137, (U); Bagley, May 30, 1927, 12206 (U); Osceola, Polk Co., May 6, 1901, *Daisy S. Howe* 24 (UM). Listed as Fimbriaria tenella.

3. *Grimaldia rupestris (Nees) Lindenb.* Burton, Grant Co., June 4, 1926, *Cheney* 11423 (U); Potosi, May 7, 1926, 11210, 1140 p. p., (ver. A. Lorenz), (U).

4. *Reboulia hemisphaerica* (L.) Raddi. Racine, Racine Co., *I. A. Lapham,* (U); Dells Wisconsin River, Sauk Co., *(collector unrecorded),* Aug. 1, 1858, (U); Madison, Dane Co., May 26, 1891, *Cheney* 2 (U); Dells Wisconsin River, Sauk Co., Aug. 9, 1893, *L. M. Underwood* (U & NY); Petanwells Rock & Germantown, Adams & Juneau Cos., July 19, 1894, *Cheney* 3704 p. p., 3705 B. (U & NY); White River Creek, July 23, 1894, (U & NY); Nakoosa, Wood Co., July 14, 1894, 3658 (U & NY); Bolin Valley, Buffalo Co., May 12, 1906, *H.* (SMS); Black River, Douglas Co., Oct.

25, 1925, *Conklin & Wilson* 1828 (SMS); Potosi, Grant Co., May 19, 1925, *Cheney* 11297 (U); same location, May 25, 1926, 11340 (U); Trempealeau Mt., Trempealeau Co., May 17, 1890, *H.* (UM); Trevip Ridge, Trempealeau Co., Nov. 1, 1892, *H.* (UM); Bradford Tp. Rock Co., Aug. 7, 1928, *Cheney* 12758 (U); Janesville, July 7, 1928, 12691, 12692 p. p. (U).

MARCHANTIACEAE

1. *Conocephalum conicum* (L) Dumort. Herb. *I. A. Lapham,* (U); Osceola, Polk Co., May 6, 1901, *Daisy S. Howe* 25 (UM); Madison, Dane Co., May 26, 1891, *Cheney,* 3 (U & NY); Lac Vieux Desert, Vilas Co., June 20, 1893, 315 (NY); Noisy Creek, Oneida Co., July 19, 1893, 1968 (U); Whirlpool Rapids, Oneida & Lincoln Cos., July 20, 1893, 2005 (U); Petanwells Rock, Adams & Juneau Cos., July 19, 1894, 3700, 3705 (U & NY); Nakoosa, Wood Co., July 14, 1894, 3658 (U); Drummond, Bayfield Co., June 26, 1896, 4313 (U); Oak Island, Ashland Co., Aug. 7, 1896, 6041 (U); Maiden Rock, Pierce Co., Aug. 12, 1916, *Allen* 42 (U); Glen Haven, Grant Co., April 13, 1921, 67 (U); Green Lake, Green Lake Co., July 16, 1922, (U); Mitchell's Glen, Green Lake, July 20, 1922, (U); Wapogasset, Polk Co., Sept. 4, 1927, (U); Winneboujou, Douglas Co., April 9, 1909, *Conklin* 1024 (SMS); Copper Creek, Aug. 5, 1909, 579, (SMS); Black River, Oct. 5, 1909, 1587, (SMS); Lake Nebagamon, Sept. 3, 1911, 1208, (SMS); Brule River, July 22, 1923, 1898 (SMS); Squaw Bay, Bayfield Co., Aug. 10, 1917, 1330 (SMS); Orienta, Sept. 23, 1923, 1946 (SMS); Siskiwit River, Oct. 5, 1924, *Conklin & Wilson* 2370 (SMS); Montreal River, Iron Co., *Conklin* 2004 Aug. 28, 1922, (SMS); Gurney Falls, Potato River, Sept. 7, 1925, 2542 (SMS); Mellen, Ashland Co., Aug. 29, 1922, 1739 (SMS); Osceola, Polk Co., Aug. 8, 1925, 2491 (SMS); Potosi, Grant Co., May 7, 1926, *Cheney* 11192 (U); Glen Haven, Grant Co., May 28, 1927, 12202 (U).

2. *Preissia quadrata* (Scop.) Nees. Madison, Dane Co., May 26, 1891, *Cheney* 5, 4 (U & NY); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 28 B, 27 B, 27 C, (U); Petanwells Rock & Germantown, Adams & Juneau Cos., July 19, 1894, *Cheney* 3700 (U & NY); Montreal River, Iron Co.,

July 19, 1896, 5149 (U); Odanah Indian Reservation, July 21, 1896, 5190 (U); Oak Island, Ashland Co., Aug. 7, 1896, 5982 (U); Sand Bay, Bayfield Co., June 25, 1897, 6478 (U); Squaw Bay, June 30, 1897, 6633 (U); Herbster and Port Wing, July 9, 1897, 7046 (U); Maiden Rock, Pierce Co., Aug. 5, 1916, *Allen* 37 (U); same location, Aug. 17, 1916, 23 (U); Glen Haven, Grant Co., Aug. 30, 1921, 72 (U); Green Lake, Green Lake Co., July 25, 1922, (U); Black River, Douglas Co., Oct. 5, 1909, *Conklin* 634 (SMS); Squaw Bay, Bayfield Co., Aug. 10, 1917, 1287 (SMS); Siskiwit Point, July 26, 1922, 1890 (SMS); Siskiwit River, July 26, 1922, 1838 (SMS); Orienta Falls, Sept. 23, 1923, 1945 B. (SMS); Mellen, Ashland Co., Aug. 26, 1922, 1739 (SMS); Gurney Falls, Potato River, Iron Co., Sept. 7, 1925, 2679 (SMS); Osceola, Polk Co., Aug. 8, 1925, 2479 (SMS); Potosi, Grant Co., May 25, 1926, *Cheney* 11341 (U); same location, May 20, 1926, 11391 (U); June 9, 1926, 11442 (U); Bagley, Grant Co., May 30, 1927, 12207 (U); Glen Haven, June 8, 1927, 12246 (U); same location, May 28, 1927, 12202 p. p. (U); Janesville, Rock Co., Sept. 3, 1928, *Cheney* 12735 (U); same location, Sept. 22, 1928, 12692 (U); Beloit, July 7, 1928, 12639 (U).

3. *Marchantia polymorpha* L. Madison, Dane Co. *I. A. Lapham,* (U); same location, Aug. 18, 1890, *Cheney & True,* (U); same location, *J. C. Carr* (U); Osceola, Polk Co., May 6, 1901, *Daisy S. Howe* 27 (UM); Blue Mounds, Iowa Co., Aug. 1, 1903, (collector unrecorded), (U); Rugby Junction Washington Co., Oct. 4, 1907, *J. F. Brenckle* (U); Devil's Lake, Sauk Co., July 11, 1903, Geol. & Nat. Hist. Survey, 113 B. (U); Crystal Lake, Vilas Co., June 17, 1893, *Cheney* 219 (U); McNaughton, Oneida Co., July 6, 1893, 1439 (U); Granite Heights, Marathon Co., June 23, 1894, 2992 (U); Petanwells Rock, Adams & Juneau Cos., July 19, 1894, 3702, 3700 (U & NY); St. Louis River, Douglas Co., July 31, 1897, 7918 (U); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 61 (U); Argyle, Lafayette Co., Sept. 17, 1925, (U); Sand Lake, Sawyer Co., Aug. 16, 1925, (U); Glen Haven, Grant Co., April 14, 1921, 70 (U); Maiden Rock, Pierce Co., Aug. 12, 1916, 45 (U); Gordon, Douglas Co., Sept. 16, 1906, *Conklin* 82 (SMS); Superior, Sept. 9, 1906, 918 (SMS); Copper Creek, Aug. 29, 1907,

289 (SMS); Black River, Oct. 3, 1910, 1045 (SMS); Brule River, July 22, 1923, 1904 (SMS); Montreal River, Iron Co., Aug. 28, 1922, 1798 (SMS); Siskiwit River, Bayfield Co., Aug. 26, 1923, 1839 (SMS); Orienta Falls, Sept. 23, 1923, 1909 (SMS); Osceola, Polk Co., Aug. 8, 1925, 2482 (SMS); Mellen, Ashland Co., Aug. 20, 1925, 2641 (SMS); Potosi, Grant Co., May 15, 1926, *Cheney* 11262 (U); same location, June 5, 1926, 11428 (U); Grant Co., 1927, 12207 (U); Bagley, May 30, 1927, 12207 p. p. (U); Bad River Gorge, Mellen, Ashland Co., Aug. 9, 1927, *Fassett & Wilson* 170 (U); Wallace Island, Lake Wapogasset, Polk Co., Sept. 3, 1927, *Allen* (U); Lake Wapogasset, Aug. 28, 1927, (U); Beloit, Rock Co., July 5, 1928, *Cheney* 12637 (U).

JUNGERMANNIALES

RICCARDIACEAE

1. *Riccardia pinguis* (L.) S. F. Gray. Lac Vieux Desert, Vilas Co., June 1893, *Cheney* 510 (NY); same location, June 22, 1893, 750 (U); Lake Nebagamon, Douglas Co., Oct. 1911, *Conklin* 1216 (SMS); Brule River, May 20, 1911, 1099 (SMS); Brule, (Whealdon's), May 1, 1925, 2516 (SMS); Orienta Falls, Bayfield Co., Sept. 3, 1923, 1921 A. (SMS); Cussen, July 25, 1913, 1341 (SMS); Mellen, Ashland Co., Sept. 9, 1927, *Fassett & Wilson* (U).

2. *Riccardia multifida* (L.) S. F. Gray. Tomahawk Lake, Oneida Co., June 29, 1893, *Cheney* 998 (U); Rainbow Rapids, July 1, 1893, 1145 (U & NY); Tomahawk Lake, July 25, 1893, 2148 (U); Black River, Douglas Co., Oct. 3, 1911, *Conklin* 1036 p.p. (SMS); Brule River, Sept. 20, 1911, 1097 (SMS); Stone's Bridge, June 12, 1916, 2156, 1438 (SMS); Mellen, Ashland Co., Sept. 7, 1927, *Fassett & Wilson* (U).

3. *Riccardia latifrons* Lindb. State Line, Vilas Co., June 6, 1893, *Cheney* 470 (U & NY); Apostle Islands, Ashland Co., Aug. 1902, *Allen,* 92 C. (U); Sand Lake, Sawyer Co., Aug. 28, 1926, (U); Solon Springs, Douglas Co., Aug. 1915, 24, 40 (U); Superior, Douglas Co., July 18, 1909, *Conklin* 776 (SMS); Black River, Oct. 3, 1911, 1136 p.p. (SMS); Lake Nebagamon, June 1, 1913, 1688 (SMS);

Stone's Bridge, Brule River, June 12, 1916, 1342 (SMS); Balsam River, Sept. 15, 1925, 2570 (SMS); Cussen, Bayfield Co., July 25, 1913, 1343 (SMS); Squaw Point, Aug. 10, 1917, 1325 (SMS).

4. *Riccardia palmata* (Hedw.) Carruth. Rainbow Rapids, Oneida Co., July 3, 1893, *Cheney* 1264 (U); Tomahawk, Lincoln Co., July 25, 1893, 2184 (U); Drummond, Bayfield Co., June 28, 1896, 4376 (U); St. Louis River, Douglas Co., July 28, 1897, 7754 (U); Solon Springs, Douglas Co., Aug. 14, 1915, *Allen* 62 (U); Solon Springs, Douglas Co., Aug. 20, 1906, *Conklin* 107 (SMS); Black River, Oct. 3, 1901, 1039 (SMS); St. Croix Lake, June 28, 1913, 1340 (SMS); Brule River, July 22, 1923, 1895 (SMS); Cornucopia, Bayfield Co., Oct. 5, 1924, *Conklin & Wilson* 2387 (SMS).

5. *Metzgeria conjugata* Lindb. Dells Wisconsin River, Sauk Co., July 7, 1884, *E. G. Knight* (NY); Coldwater Canon, Adams Co., July 30, 1894, *Cheney* 3830 (NY & U).

6. *Pallavicinia flotowiana* (Nees) Lindb. Brule River, (Whealdon's), Douglas Co., July 22, 1923, *Conklin* 1850 (SMS).

PELLIACEAE

1. *Pellia epiphylla* (L.) Corda. Dells Wisconsin River, Sauk Co., Aug. 19, 1898, *L. M. Underwood* (NY & U); Grand Rapids, Wood Co., July 9, 1894, *Cheney* 3629 (NY & U); Wisconsin River, Adams & Juneau Cos., July 27, 1894, 3788 (NY & U); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 29 A, 29 B, 27 A, 27 C, (U); Solon Springs, Douglas Co., Aug. 22, 1915, 1, 18 (U); Lac Vieux Desert, Vilas Co., Aug. 27, 1917, 57 (U); Eau Claire Lakes, Bayfield Co., Aug. 8, 1925, 71 (U); Lake Wapogasset, Polk Co., Aug. 28, 1927, (U); Gordon, Douglas Co., Aug. 1907, *Conklin* 316 (SMS); Copper Creek, May 5, 1909, 587 (SMS); Black River, Oct. 3, 1910, 1012, 1043 (SMS); Squaw Point, Bayfield Co., Aug. 26, 1922, 1808 (SMS); Montreal River, Iron Co., Sept. 6, 1925, 2551 (SMS); Mellen, Ashland Co., Sept. 7, 1927, *Fassett & Wilson* (U); Barron, Barron Co., April 26, 1928, *Cheney* 12565 (U & SMS).

2. *Pellia fabroniana* Raddi. Barron, Barron Co., Aug. 13, 1891, *Cheney* 64 (NY & U); Granite Heights, Mara-

thon Co., June 22, 1894, 3018 (NY & U); Knowlton, Portage Co., June 30, 1894, 3364 (NY & U); Mason, Bayfield Co., July 8, 1896, 4686 (NY & U); Houghton Quarries, July 25, 1896, 5429, 5457 (NY & U); Black River, Douglas Co., April 9, and Oct. 7, 1911, *Conklin* 1066, 1026 (SMS); Winneboujou, May 20, 1911, 1405 (SMS); Orienta Falls, Bayfield Co., Sept. 23, 1923, 1933 (SMS).

3. *Pellia neesiana* (Gottsche) Limpr. Eagle River, Vilas Co., June 27, 1893, *Cheney* 888 (NY & U); Rainbow Rapids, Oneida Co., July 5, 1893, 1381 (NY & U); Newbold, July 10, 1893, 1548 (NY & U); White River, Bayfield Co., July 9, 1896, 4686 (U); Montreal River, Iron Co., July 19, 1896, 5029 (U); Houghton Quarries, Bayfield Co., July 25, 1896, 5429, 5457 (U); Devils Lake, Sauk Co., Aug. 16, 1917, *Allen* 25 (U); Lake Wapogasset, Polk Co., Sept. 4, 1927, (U); Gordon, Douglas Co., Sept. 16, 1906, *Conklin* 316 (SMS); Solon Springs, May 1908, 100 (SMS); Winneboujou, April 9, 1910, 1027 (SMS); Black River, Oct. 3, 1910; 1045 (SMS); Stone's Bridge, Brule River, June 12, 1916, 1436 (SMS); Mud Creek, June 7, 1925, 2473 (SMS); Squaw Point, Bayfield Co., Aug. 10, 1817, 1298 (SMS); Siskiwit Point, Oct. 5, 1924, 2375 (SMS); Cornucopia, Oct. 4, 1924, 2381 (SMS).

4. *Blasia pusilla* L. Newbold to Rhinelander, Oneida Co., July 10, 1893, *Cheney* 1541 (NY & U); Drummond, Bayfield Co., June 22, 1896, 4065, 4249 (NY & U); Montreal River, Iron Co., July 21, 1896, 5173 (U); Oak Island, Ashland Co., Aug. 7, 1896, 6007 (U); Herbster, Bayfield Co., Aug. 1, 1897, 6908 (U); Opposite Fond du Lac, Douglas Co., Aug. 1, 1897, 7990 (U); Black River, Douglas Co., Oct. 3, 1910, *Conklin* 1040 (SMS); Squaw Bay, Bayfield Co., Aug. 10, 1917, 1328 (SMS); Bark Point, July 27, 1923, 1929 (SMS); Siskiwit Point, July 29, 1923, 1888 (SMS); Orienta, Sept. 23, 1923, 1849 (SMS); Montreal River, Iron Co., Sept. 6, 1925, 2579 (SMS); Gurney Falls, Sept. 7, 1925, 2539 (SMS); Apostle Islands, Ashland Co., Aug 1902, *Allen* 6, 15 (U); Pine Creek, Maiden Rock, Pierce Co., Aug. 15 and 16, 1916, 49, 50, 27 (U); St. Croix Falls, Polk Co., July 12, 1890 *H.* (UM); Mellen, Ashland Co., Sect. 17, July 9, 1927, *Fassett & Wilson,* (U); Bad River Gorge,

Aug. 9, 1927, (U); Barron, Barron Co., Nov. 17, 1929, *Cheney* 12931 (U & SMS).

5. *Fossombronia foveolata* Lindb. Witch's Gulch, Adams Co., July 31, 1891, *Cheney* 3883 (NY & U; Apostle Islands, Ashland Co., Aug. 1902, *Allen* 28 A. (U); Siskiwit River, Bayfield Co., July 29, 1923, *Conklin* 1847 (SMS); Arena, Iowa Co., Sept 1, 1922, *Allen* (U); (Specimen collected is immature, lacks spores and cannot be named with any certainty.)

LOPHOZIACEAE

1. *Plagiochila asplenioides* (L.) Dumort. Dells Wisconsin River, Sauk Co., July 7, 1883, *E. G. Knight* 12 (NY); same location, July 8, 1893 (NY); same location Aug. 19, 1893, *L. M. Underwood* (NY); Lac Vieux Desert, Vilas Co., June 22, 1893, *Cheney* 547 (U); McNaughton to Newbold, Oneida Co., July 8, 1893, 1526 (U); Mason, Bayfield Co., July 8, 1896, 4641 (NY & U); Montreal River, Iron Co., July 19, 1896, 5050 (U); same location. July 21, 1896, 5207 (U); Witch's Gulch, Adams Co., July 28, 1896, 3892 (U); Presque Isle, Ashland Co., Aug. 6, 1896, 5951 (U); Herbster, Bayfield Co., July 7, 1897, 6906, 6944 p.p. 6947 (U); Port Wing, July 8, 1897, 7010 (U); same location, July 12, 1897, 7214 (U); Brule River, Douglas Co., July 19, 1897, 7525 (U); St. Louis River, July 31, 1897, 7963, (U); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 25 B, 25 (U); Devils Lake, Sauk Co., Aug. 6, 1915, 20, 39 (U); Solon Springs, Douglas Co., Sept. 5, 1915, 64 (U); Solon Springs, Douglas Co., Summer 1907, *Conklin* 294 (SMS); Copper Creek, Aug. 5, 1909, 542 (SMS); Black River, Oct. 5, 1909, 663 (SMS); Brule River, May 7, 1911, 1220 (SMS); Lake Nebagamon, July 1, 1913, 1774 (SMS); Stone's Bridge, June 12, 1916, 1414 (SMS); Squaw Point, Bayfield Co., Aug. 10, 1917, 1332 (SMS); same location, Aug. 26, 1922, 1976 (SMS); Bark Point, Bayfield Co., July 27, 1923, 1880 (SMS); Siskiwit Point, Sept. 1, 1923, 1891 (SMS); Cornucopia, Oct. 5, 1924, 2439 (SMS); Montreal River, Iron Co., Aug. 28, 1922, 2001 (SMS); same location, Sept. 6, 1925, 2561 (SMS); Barron, Barron Co., March 31, 1927, *Cheney* 21080 (U); Bag-

ley, Grant Co., June 4, 1927, 12227 (U); Mellen, Ashland Co., Sept. 7, 1927, *Fassett & Wilson* (U).

2. *Mylia anomala* (Hook.) S. F. Gray. Black River, Douglas Co., Oct. 3, 1910, *Conklin* 961 (SMS); Superior, June 4, 1911, 1104, 2224 (SMS); Stone's Bridge, Brule River, June 26, 1916, 1437 (SMS).

3. *Lophocolea heterophylla* (Schrad.) Dumort. Milwaukee, Milwaukee Co., July 1, 1862, *I. A. Lapham* (U); Madison, Dane Co., April 19, 1890, *Cheney & True* (U); Fayette, Lafayette Co., Dec. 1891, *Cheney* 7, 17 (NY & U); Lake Mills, Jefferson Co., March 30, 1891, G, H, I, K, M, N, (NY & U); Dells Wisconsin River, Sauk Co., Aug. 19, 1893, *L. M. Underwood* (NY & U); Lac Vieux Desert, Vilas Co., June 13, 1893, *Cheney* 52 (U); same location, June 20, 1893, 355 (U); State Line, June 21, 1893, 740 p.p. (U); Thomas' Place, Lac Vieux Desert, June 22, 1893, 578, 576 (U); Rhinelander, Oneida Co., July 18, 1893, 1824 (NY & U); Tomahawk, Lincoln Co., July 27, 1893, 2297 p.p., 2359 (U); Mosinee, Marathon Co., July 27, 1894, 3231 (U); same location, July 28, 1894, 3308 (U); Coldwater Canon, Adams Co., July 30, 1894, 3814 (U); Drummond, Bayfield Co., June 29, 1896, 4376 (NY & U); Herbster, July 7, 1897, 6882, 6948 (U); Port Wing, July 12, 1897, 7185 p.p. (U); White River, Ashland Co., July 13, 1896, 4781 (U); Wilson Island, Aug. 6, 1896, 5901, 5939 (NY & U); Blue Mounds, Iowa Co., Aug. 1, 1903, (U).

Two specimens Madison, Dane Co., April and May 1891, *Cheney;* and Baraboo, Sauk Co., *R. H. True* (NY & U); are referred here. Both are named Lophocolea bidentata (L.) Dumort. The dioecious inflorescence of L. bidentata cannot be determined from condition of the specimens. They are referred therefore to Lophocolea heterophylla (Schrad.) Dumort. Barron, Barron Co., March 31, 1927, *Cheney* 12107 (U); Glen Haven, Grant Co., May 6, 1927, 12145 (U); same location, May 11, 1927, 12154 (U); May 31, 1927, 12213 (U); Bagley, Grant Co., May 20, 1927, 12187 (U); Bear Trap Lake, Polk Co., Aug. 30 and Aug. 31, Sept. 3, and Sept. 8, 1927, *Allen* (U); Lake Wapogasset, Aug. 28, Sept. 4, 1927, (U); Wallace Island, Lake Wapogasset, Sept. 3, 1927 (U); Apostle Islands, Ashland Co., Aug. 1902, 78 C, 79 C, 22 A, 79 A, 19 B, 22 B, 64 B, 30 B, 51 A, 78 B, 92 A, 23, 91 B, 79 B, 42 A, (U); Devil's Lake, Sauk Co., July 11, 1903, (*collector unrecorded*), (U); Green Lake, Green Lake Co., July 16, 1922, *Allen* (U); Argyle, Lafayette Co., Sept. 17, 1925, (U); Sand Lake, Sawyer Co., Aug. 12 to 28, 1925, (U); Solon Springs, Douglas Co., Aug. 5 to 14, 1915, 6, 14, 15, 29, 53, 69, 24, 47, 11 (U); Maiden Rock, Pierce Co., Aug. 15, 1915, 27 (U); Eau Claire Lake, Bayfield Co., Aug. 8, 1925, 66 (U); Oconomowoc, Waukesha Co., June 27, 1925, *Wilson* (SMS); Solon Springs, Douglas Co., May 29, 1907, *Conklin* 423 (SMS); Superior, July 18, 1909, 760 (SMS); Copper Creek, Aug. 29, 1909, 379 (SMS); Lake Nebagamon, Sept. 3, 1911, 1149 (SMS); Black River, Oct. 2, 1912, 1064 (SMS); Brule River, (Whealdon's), July 22, 1923, 1977 (SMS); Squaw Point, Bayfield Co., Aug. 10, 1917, 1333 (SMS); Lake Namekagon, Ashland Co., Aug. 14, 1924, 2276 (SMS): Marshland, Buffalo Co., June 23, 1902, *H.* (UM); same location, June 24, 1902, (UM); Mellen, Ashland Co., Sect. 16, July 9, 1927, *Fassett & Wilson* (U); St. Croix Falls, Polk Co., Sept. 4, 1927, (U); Barron, Barron Co., March 31, 1927, *Cheney* 12081, 12088, 12095, 12099 (U); Glen Haven, Grant Co., June 10, 1927, 12257 p.p. (U); Bradford Tp., Rock Co., Aug. 2, 1928, *Cheney* 12783 (U); Clinton, Aug. 14, 1928, 12791 (U); Neward Tp., Aug. 25, 1928, 12807 (U); same location, Oct. 4, 1928, 12845 (U); Oct. 18, 1928, 12845 (U).

4. *Lophocolea minor* Nees. Fayette, Lafayette Co., Dec. 1891, *Cheney* 11 (NY); Grandmother Bull Falls, Lincoln Co., July 29, 1893, 2580 (NY & U); Mosinee, Marathon Co., June 27, 1894, 3308 (N Y& U); Stevens Point, Portage Co., July 4, 1894, 3486 (NY & U); Mason, Bayfield Co., July 8, 1896, 4645 (NY & U); Montreal River, Iron Co., July 21, 1896, 5128 (U); Montreal River, and Odanah Indian Reservation, July 21, 1896, 5191 (U); St. Louis River, Douglas Co., July 30, 1897, 7882 (U); Dells Wisconsin River, Kilbourn, Sauk Co., Aug. 13, 1912, *M. F. Somerville* (SMS); Black River, Douglas Co., Oct. 5, 1909, *Conklin* 673 (SMS); (Whealdon's), Brule River, Aug. 24, 1924, 2279 B. (SMS); Brule River, May 7, 1925, 2511 (SMS); Montreal River, Iron Co., Aug. 27, 1922, 1799 (SMS); Orienta Falls, Bayfield Co., Sept. 23, 1923, 1943 (SMS); Potosi, Grant Co., May 7, 1926, *Cheney* 11200 (U); same location, May

28, 1926, 11369 (U); Werley, Sept. 16, 1927, 12433 (U); Glen Haven, May 16, 1927, 12168 (U); Bagley, June 8, 1927, 12253 (U); St. Croix Falls, Polk Co., Sept. 4, 1927, *Fassett & Wilson* (U); Marshland, Buffalo Co., June 24, 1902, *H.* (UM & SMS); Winona Bluffs, Wisconsin side, Oct. 27, 1902, (UM); Glen Haven, Grant Co., June 10, 1927, *Cheney* 12257 p.p. (U); Bradford Tp., Rock County, Aug. 14, 1928, *Cheney* 12792 (U); same location, Sept. 1, 1928, 12811 (U).

5. *Chiloscyphus pallescens* (Ehrh.) Dumort. Noisy Creek, Oneida Co., July 19, 1893, *Cheney* 1964 (U); Wilson Island, Ashland Co., Aug. 1896, 5901 (U); Herbster, Bayfield Co., July 7, 1897, 6682 p. p. (U); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 62 (U); Maiden Rock, Pierce Co., Aug. 17, 1915, 30 (U); Copper Creek, Douglas Co., Sept. 15, 1902, *Conklin* 250 (SMS); same location, Aug. 5, 1906, 591 (SMS); Gordon, Aug. 1907, 522 (SMS); Winneboujou, May 20, 1911, 1407, (SMS); Black River, Aug. 16, 1922, 1778 (SMS); (Whealdon's), Brule River, July 22, 1923, 1896 (SMS); Stone's Bridge, Aug. 24, 1921, 2280 (SMS); Mellen, Ashland Co., Aug. 29, 1922, 1992 (SMS); Montreal River, Iron Co., Aug. 26, 1923, 1974, 1982 (SMS); Siskiwit River, Bayfield Co., Sept. 1, 1923, 1910 (SMS); Bark Point, Oct. 4, 1924, 2434 (SMS); St. Croix Lake, Douglas Co., Nov. 2, 1924, 2419 (SMS); Bridgeport, Grant Co., July 19, 1927 *Cheney* 12346 (U); Bagley, August 24, 1927, 12390 (U); Lake Wapogasset, Polk Co., Sept. 4, 1927, *Allen* (U).

6. *Chiloscyphus fragilis* (Roth) Schiffn. Tomahawk Lake, Oneida Co., June 29, 1893, *Cheney* 1032 (U); Whirlpool Rapids, Oneida & Lincoln Cos., July 20, 1893, 1980 (U); Argyle, Lafayette Co., Sept. 17, 1925, *Allen* (U); Lake Nebagamon, Douglas Co., May 7, 1911, *Merryman* 1259 (SMS); Stone's Bridge, June 12, 1916, *Conklin* 2195 (SMS); Squaw Bay, Bayfield Co., Aug. 10, 1917, 1326 (SMS); Stone's Bridge, Douglas Co., July 4, 1924, 2203 (SMS); St. Croix Lake, Nov. 2, 1924, 2421 (SMS); Mud Creek, July 7, 1925, 2474 (SMS).

7. *Chiloscyphus rivularis* (Schrad.) Loeske. Whirlpool Rapids, Oneida & Lincoln Cos., June 20, 1893, *Cheney* 1992 (NY & U); Rainbow Falls, Oneida Co., July 1893, 1032

(NY & U); Knowlton, Marathon Co., June 30, 1894, 3349 (NY & U); Witch's Gulch, Adams Co., July 31, 1894, 3898 (U); Houghton Quarries, Bayfield Co., July 25, 1896, 5483 (U); Winneboujou, Douglas Co., April 9, 1910, *Conklin* 1113 (SMS); same location, July 4, 1910, 1032 (SMS); Stone's Bridge, Brule River, June 12, 1916, 1411 (SMS); Brule River, May 1, 1923, 2499 (SMS); Hatfield, Jackson Co., Oct. 25, 1907, *H.* (UM & SMS).

8. *Chiloscyphus polyanthos* (L.) Corda. Copper Creek, Douglas Co., Sept. 15, 1902, *Conklin* 458 (SMS); Superior, Sept. 12, 1909, 718 (SMS); Stone's Bridge, June 20, 1916, 1428 (SMS); Black River, July 26, 1922, 1767 (SMS); St. Croix Lake, June 29, 1924, 2227 (SMS); Solon Springs, Sept. 12, 1915, *Allen* 2, 4, 73 (U).

9. *Harpanthus scutatus* (Web. & Mohr) Spruce. Fayette, Lafayette Co., Dec. 1891, *Cheney* 12 (NY); Grandmother Bull Falls, Lincoln Co., July 29, 1893, 2672 (NY & U); Grand Rapids, Wood Co., July 9, 1894, 3631 (NY & U); Coldwater Canon, Adams Co., July 30, 1894, 3814 p. p. (U); Montreal River, Iron Co., July 22, 1896, 5244 p. p. (U); Houghton Quarries, Bayfield Co., July 25, 1896, 5493 (U); Solon Springs, Douglas Co., July 1, 1909, *Conklin* 470 (SMS); Black River, Oct. 5, 1909, 1354 (SMS); Squaw Bay, Bayfield Co., Aug. 10, 1917, 1291 (SMS); Brule River, Douglas Co., May 1, 1925, 2518 (SMS); Sand Lake, Sawyer Co., Sept. 28, 1925, *Allen* (U); Bass Lake, Sept. 15, 1925, (U); Solon Springs, Douglas Co., Aug. 1915, 7, 28, (U); Glen Haven, Grant Co., Aug. 16, 1926, *Cheney* 11668 (U); same location, June 10, 1927, 12257 (U); Patch Grove, Sept. 22, 1927, 12454 (U); same location, Sept. 24, 1927, 12465 (U); Bagley, Aug. 25, 1927, 12391 (U); Bear Trap Lake, Polk Co., Sept. 8, 1927, *Allen* (U).

10. *Geocalyx graveolens* (Schrad.) Nees. Lac Vieux Desert, Vilas Co., June 14, 1893, *Cheney* 82 p. p. (U); State Line, June 14, 1893, 469 p. p. (U); Eagle River, Oneida Co., June 28, 1893, 952 p. p. (U); Rainbow Rapids, July 3, 1893, 1264 p. p. (U); Coldwater Canon, Adams Co., July 30, 1894, 3814 p. p. (U); Mason, Bayfield Co., July 7, 1896, 4367 (NY); Oak Island, Ashland Co., Aug. 7, 1896, 5992 p. p. (NY); Brule Swamp, Douglas Co., Aug. 9, 1915, *Allen* 17 (U); same location, Aug. 13, 1915, 56 (U); Solon Springs,

Douglas Co., Oct. 1907, *Conklin* 387 (SMS); Superior, Sept. 6, 1909, 489 (SMS); Winneboujou, April 9, 1910, 1030 (SMS); Hall's Swamp, Winneboujou, May 20, 1911, 1460 (SMS); Lake Nebagamon, June 13, 1913, 1775 (SMS); Head St. Croix Lake, June 25, 1913, 1391 (SMS); Cornucopia, Bayfield Co., Sept. 1, 1913, 1873 (SMS); Stone's Bridge, Douglas Co., June 12, 1916, 2198 (SMS); Squaw Point, Bayfield Co., Aug. 11, 1917, 1280 (SMS); Mellen, Ashland Co., Aug. 29, 1922, 1806 (SMS); Siskiwit Point, Bayfield Co., July 29, 1923, 1889 (SMS); Montreal River, Iron Co., Sept. 6, 1925, 2559 (SMS); Barron, Barron Co., March 31, 1927, *Cheney* 12098, 12104, 12105, 12115 (U); Marshland, Buffalo Co., June 1903, *H.* (UM).

11. *Nardia crenulata* (Smith) Lindb. Arena, Iowa Co., Sept. 1, 1922, *Allen* (U).

12. *Nardia hyalina (Lyell) Carringt.* Fayette, Lafayette Co., Dec. 1891, *Cheney* (NY); Dells Wisconsin River, Sauk Co., Aug. 19, 1893, *L. M. Underwood* (NY); Nakoosa, Wood Co., July 14, 1894, *Cheney* 3659 (NY & U); Petanwells Rock, Adams & Juneau Cos., July 16, 1894, 3680 (NY & U); same location, July 19, 1894, 3702, 3703, 3704 (NY & U); Witch's Gulch, Adams Co., July 31, 1894, 3883 (U); Montreal River, Iron Co., July 20, 1896, 5115, 5128, 5152 (NY & U); Houghton Quarries, Bayfield Co., July 25, 1896, 5429 p. p., 5444 (U); Herbster, July 7, 1897, 6867, 6907, 6946 p. p. (U); Galesville, Trempealeau Co., 1919, 150 *H.* (Yale U); Apostle Island, Ashland Co., Aug. 1902, *Allen* 27 A, (U); Squaw Point, Bayfield Co., Aug. 10, 1917, *Conklin* 2322, 1276, 1282, 1289 (SMS); Siskiwit Point, Aug. 27, 1922, 1813 (SMS); Bark Point, Sept. 23, 1923, 1980 (SMS); Orienta Falls, Sept. 23, 1923, 1924 (SMS); Herbster, Sept. 23, 1923, 1920 (SMS); Black River, Douglas Co., 1921, *Conklin* 1302 (SMS); Amnicon Falls, Oct. 5, 1924, 2019 (SMS); Marshland, Buffalo Co., June 23, 1902, *H.* (UM); same location, June 24, 1902, (UM & SMS); Bagley, Grant Co., June 4, 1927, *Cheney* 12230 (U); Patch Grove, Sept. 24, 1927, 12390 p. p. (U).

13. *Jungermannia lanceolata* L. Fayette, Lafayette Co., Dec. 1891, *Cheney* (NY); Pine River, Lincoln Co., Aug. 3, 1893, 2864 (U); White River, Bayfield Co., July 8, 1896, 4634, 4637 (U); St. Louis River, Douglas Co., July 28,

1897, 7778 (U); Brule Swamp, Solon Springs, Douglas Co., Aug. 9, 1915, *Allen* 17 A (U); Winneboujou, April 9, 1911, *Conklin* 1026 (SMS); Black River, Oct. 5, 1912, 1653 (SMS); Stone's Bridge, June 12, 1916, 2193 (SMS); (Whealdon's), Brule River, Oct. 7, 1923, 1900 (SMS); Bark Point, Bayfield Co., July 27, 1923, 1851 (SMS); Siskiwit River, Oct. 5, 1924, 2374 (SMS); Montreal River, Iron Co., Sept. 6, 1925, 2559 (SMS).

14. *Jungermannia pumila* With. Petanwells Rock, Adams & Juneau Cos., July 19, 1894, *Cheney* 3702 (U); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 29 A (U); Copper Creek, Douglas Co., Aug. 5, 1909, *Conklin* 551 (SMS); Black River, Oct. 3, 1909, 626 (SMS); same location, July 6, 1921, 1303 (SMS); (Whealdon's), Brule River, Oct. 7, 1923, 2015 (SMS); Squaw Point, Bayfield Co., Aug. 10, 1917, 1310, 1290 (SMS); Siskiwit River, Aug. 26, 1922, 1781 (SMS); Orienta Falls, Sept. 23, 1923, 1923 (SMS); Bark Point, Sept. 23, 1923, 1926 (SMS); Montreal River, Iron Co., Aug. 28, 1922, 2005 (SMS); same location, Sept. 6, 1925, 2549 (SMS); Trevip Ridge, Trempealeau Co., Nov. 11, 1892, *H.* (UM).

15. *Jungermannia pumila* var. *rivularis* Schiffner. Siskiwit River, Bayfield Co., Aug. 26, 1922, *Conklin* 1780 (SMS); Montreal River, Iron Co., Aug. 28, 1922, 1954 (SMS).

16. *Jungermannia cordifolia* Hook. White River, Ashland Co., *Cheney* July 13, 1896 4778 (NY & U).

17. *Jungermannia schiffneri* (Loitles.) Evans. Black River, Douglas Co., Oct. 3, 1910, and April 15, 1915, *Conklin* 1255, 1214, 1003 (SMS); Amnicon Falls, Aug. 12, 1923, 1867 (SMS); (Whealdon's), Brule River, Oct. 7, 1924, 2013 (SMS); Squaw Point, Bayfield Co., May 10, 1917, 1321 (SMS); same location, Aug. 26, 1922, 1785 (SMS); Siskiwit River, Sept. 27, 1923, 1832 (SMS); Montreal River, Iron Co., Aug. 27, 1922, 1819 (SMS); same location, Sept. 7, 1925, 2550 (SMS).

18. *Jungermannia sphaerocarpa* Hook. Apostle Islands, Ashland Co., Aug. 1902, *Allen* 29 A (U); Orienta Falls, Bayfield Co., Sept. 23, 1923, *Conklin* 1944 (SMS).

19. *Jamesoniella autumnalis* (DC.) Steph. Fayette, Lafayette Co., Dec. 1891, *Cheney* (NY); Lac Vieux Desert,

Vilas Co., June 13, 1893, 10, 55, 47 (U); State Line, June 21, 1893, 469, 636 p. p. (NY & U); Rainbow Rapids, Oneida Co., July 3, 1893, 1264 p. p., 1262 A (U); Newbold, July 10, 1893, 1757 (U); Granite Heights, Marathon Co., June 22, 1894, 2994 p. p., 2954, 2999 (U); same location, June 23, 1894, 2981 (U); Mason, Bayfield Co., July 7, 1896, 4615, 4632 (NY & U); White River, July 8, 1896, 4633 p. p. 4635, 4646 (NY & U); Herbster, Cranberry River, July 7, 1897, 6895, 6896 p. p. (U); Port Wing, July 12, 1897, 7185 (U); La Chapelle, and Brule, Bayfield & Douglas Cos., July 17, 1897, 7425 (U); Monteral River, Iron Co., July 21, 1896, 5173 p. p. 5175 (NY & U); St. Louis River, Douglas Co., July 28, 7753, (U); same location, July 29, 1897, 7751 (U); July 31, 1897, 7912 p. p. 7916 p. p. (U); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 13, 42 A, 92 B, 64, 12 B, 14 B, 42 B, 78 A, 14 A, 43 A, 22 A, 79 A, 19 B, 64 B, (U); Devil's Lake, Sauk Co., Aug. 6, 1915 , 20 (U); Sand Lake, Sawyer Co., Aug. 13, 1925, (U); Bass Lake, Aug. 15, 1925, (U); Solon Springs, Douglas Co., Aug. 1915, 19, 21, 26, 31, 33, 36, 60, 63, 68, 47, (U); Solon Springs, Douglas Co., Oct. 1907, *Conklin* 410 (SMS); Copper Creek, Aug. 5, 1909, 594 (SMS); Superior, Nov. 14, 1909, 607 (SMS); Black River, Oct. 3, 1910, 1071 (SMS); Brule River, April 15, 1912, 1208 A (SMS); Stone's Bridge, June 12, 1916, 2200 (SMS); Squaw Point, Bayfield Co., Aug. 10, 1917, 1329 (SMS); Siskiwit Point, Oct. 5, 1924, 2437 (SMS); Potosi, Grant Co., May 19, 1926, *Cheney* 11309 (U); Glen Haven, May 11, 1927, 12153 (U); Bagley, June 4, 1927, 12229, 12228 (U); Lancaster, Oct. 24, 1927, 12538 (U); Mt. Hope, Oct. 15, 1927, 12518 (U); Mellen, Ashland Co., Sect. 16, Sept. 7, 1927, *Fassett & Wilson,* (U); Loon Lake, Mellen, Sept. 8, 1927, (U); Bad River Gorge, Sept. 8, 1927, (U); Bear Trap Lake, Polk Co., Sept. 8, 1927 *Allen* (U); Lake Wapogasset, Aug. 31, and Sept. 4, 1927, (U); Newark Tp., Rock Co., Aug. 25, 1925, *Cheney* 12808 (U).

20. *Lophozia alpestris* (Schleich.) Evans. Goodrich, Marathon Co., June 25, 1894, *Cheney* 3194 (NY & U); Oak Island, Ashland Co., Aug. 7, 1896, 6023 (NY & U); Wilson Island, Aug. 6, 1896, 5895 (U); Squaw Point, Bayfield Co.,

Aug. 10, 1917, *Conklin* 1275 (SMS); Orienta Falls, Sept. 23, 1923, 1918, 1950 (SMS).

21. *Lophozia attenuata* (Mart.) Dumort. Black River, Douglas Co., July 9, 1923, *Conklin* 1538 (SMS).

22. *Lophazia badensis* (Gottsche) Schiffn. Montreal River, Iron Co., July 20, 1896, *Cheney* 5149 (U); Lake Superior, 3 miles from Montreal River, July 22, 1896, 5198 (U); Black River, Douglas Co., Oct. 5, 1912, 1360 (SMS) same location, April 15, 1915, 1255 (SMS); Mellen, Ashland Co., Aug. 28, 1922, 1854 (SMS); Siskiwit Point, Bayfield Co., July 29, 1923, 1855 (SMS); Squaw Point, Aug. 26, 1923, 1970 (SMS); Orienta Falls, Sept. 23, 1923, 1948 (SMS); Montreal River, Iron Co., Aug. 28, 1923, 1993, 1995 (SMS); Gurney Falls, Sept. 7, 1925, 2538 (SMS); Mellen, Ashland Co., Aug. 23, 1925, 2642 (SMS).

23. *Lophozia barbata* (Schreb.) Dumort. Lac Vieux Desert, Vilas Co., June 14, 1893, *Cheney* 105 (U); Wisconsin River, Oneida Co., June 19, 1893, 1844 (NY & U); Grandmother Bull Falls, Lincoln Co., July 29, 1893, 2559 2650, 2643 (NY & U); Between Herbster and Port Wing, Bayfield Co., July 8, 1897, 7040 (U); St. Croix Falls, Polk Co., Nov. 1897, C. F. Baker 94 (NY); Devil's Lake, Sauk Co., July 11, 1903, (U); Copper Creek, Douglas Co., Aug. 29, 1907, *Conklin* 232 (SMS); Black River, Oct. 3, 1910, 1086 (SMS); Montreal River, Iron Co., Aug. 28, 1922, 1787, 2022, 2003 (SMS); Gurney Falls, Potato River, Sept. 7, 1925, 2540 (SMS); Cornucopia, Bayfield Co., July 26, 1922, 1998 (SMS); Bark Point, July 27, 1923, 1878 (SMS); Orienta Falls, Oct. 4, 1924, 2388 (SMS); Mellen, Ashland Co., Aug. 29, 1922, 1792 (SMS); St. Croix Falls, Polk Co., Sept. 4, 1927, *Fassett & Wilson* (U); Mellen Ashland Co., Sept. 8, 1927, (U); Bad River Gorge, Mellen, Sept. 8, 1927, (U); St. Croix Falls, Polk Co., June 19, 1927, *Mary E. Van Wert* 37H (SMS).

24. *Lophozia bicrenata* (Schmid.) Dumort. Amnicon Falls, Douglas Co., Oct. 1, 1922, *Conklin* 1740 (SMS).

25. *Lophozia excisa* (Dicks.) Dumort. Siskiwit River, Bayfield Co., Sept. 1, 1923, *Conklin* 1853 (SMS).

26. *Lophozia guttulata* (Lindb. & Arnell) Evans. Lake Nebagamon, Douglas Co., June 1, 1913, *Conklin* 2063 (SMS).

27. *Lophozia heterocolpa* (Thed.) M. A. Howe. White River, Ashland Co., July 13, 1896, *Cheney* 4781 (NY & U); Herbster, Bayfield Co., July 7, 1897, 6944 (U); Port Wing, July 14, 1897, 7274 (U); Copper Creek, Douglas Co., Oct. 5, 1909, *Conklin* 566 (SMS); Black River, Oct. 5, 1912, 1346, 1580 (SMS); Mellen, Ashland Co., Aug. 29, 1922, 1793 (SMS); Montreal River, Iron Co., Aug. 28, 1922, 1830, 1973 (SMS); same location Sept. 6, 1925, 2578 (SMS).

28. *Lophozia incisa.* (Schard.) Dumort. Lac Vieux Desert, Vilas Co., June 14, 1893, *Cheney* 82 (NY & U); Canover, June 26, 1893, 825 (NY & U); Rainbow Rapids, Oneida Co., July 3, 1893, 1247, 1254, 1255, 1380 (U); Coldwater Canon, Adams Co., July 10, 1894, 3823 p. p. (U); Drummond, Bayfield Co., June 26, 1896, 4303 (U); St. Louis River, Douglas Co., July 31, 1897, 7908, 7911 (U); Solon Springs, Douglas Co., Aug. 9, 1915, *Allen* 16, 56, 59 (U); Superior, Douglas Co., July 18, 1909, *Conklin* 775 (SMS); Copper Creek, Aug. 5, 1909, 529 (SMS); Black River, Oct. 2, 1910, 1065 (SMS); Solon Springs, June 28, 1913, 1345 (SMS); Brule River, June 12, 1916, 1347 (SMS); Montreal River, Iron Co., Aug. 28, 1922, 1975 (SMS); Mellen, Ashland Co., Aug. 29, 1922, 1905 (SMS); Siskiwit River, Bayfield Co., Oct. 5, 1924, 2388, 2308 (SMS); Barron, Barron Co., March 31, 1927, *Cheney* 12,-100, 12108 p. p., 12110, 12117 (U); Patch Grove, Grant Co., Sept. 24, 1927, 12463 B. p. p. (U); Mellen, Ashland Co., Sect. 16, July 9, 1927, *Fassett & Wilson* (U).

29. *Lophozia kaurini* (Limpr.) Steph. Houghton Quarries, Bayfield Co., July 28, 1896, *Cheney* 5435 (U); Port Wing, July 14, 1897, 7274 (U); Oak Island, Ashland Co., July 28, 1896, 5993 (U); Apostle Islands, Ashland Co., Aug. 1902, Allen 26 B., 27 D., 27 A. p. p. 39 C., 27 C. (U); Black River, Douglas Co, Oct. 3, 1910, *Conklin* 1138 (SMS); Squaw Point, Bayfield Co., Aug. 10, 1917, 1324, 1285 (SMS); same location, Aug. 26, 1922, 1796, 1788 (SMS); Siskiwit Point, July 29, 1923, 2027 (SMS); Mellen, Ashland Co., Aug. 29, 1922, 1739 (SMS); Montreal River, Iron Co., Aug. 28, 1922, 1989 (SMS).

30. *Lophozia longiflora* (Nees) Schiffn. Black River, Douglas Co., Oct. 5, 1912, *Conklin* 1208 (SMS).

31. *Lophozia muelleri* (Nees) Dumort. Black River, Douglas Co., Oct. 3, 1910, *Conklin* 1002 (SMS); Squaw Point, Bayfield Co., Aug. 10, 1917, 1323 (SMS).

(Recent studies of a large number of specimens of Lophozia badensis from this region show a wide range of variability in the size of the plants, margin of the bracts, size of the leaf cell and cell structure. The above species may be found upon further study, to be a robust form of L. badensis. Lophozia badensis is rather common throughout Douglas, Bayfield and Iron counties, where similar habitats are found; namely: The spray wet seams and crevasses along the trap rock gorges of the streams cutting the South Shore Range of Lake Superior.)

32. *Lophozia porphyroleuca* (Nees) Schiffn. Lac Vieux Desert, VilasCo., June 1893, *Cheney* 59 p. p. (U); same location, June 14, 1893, 82 (U); State Line, June 21, 1893, 469 p. p., 470 p. p. (U); Rainbow Rapids, Oneida Co., July 5, 1893, 1263, 1264 (U); Roy's Points, Ashland Co., Aug. 5, 1896, 5850 (NY & U); Apostle Islands, Ashland Co., Aug. 1902, Allen 51 B (U); Superior, Douglas Co., Sept. 6, 1909, *Conklin* 724 (SMS); Black River, Oct. 3, 1910, 1006 (SMS); same location, Oct. 5, 1912, 1525 (SMS).

33. *Lophozia quinquedentata* (Huds.) Cogn. Cooper Creek, Douglas Co., Aug. 5, 1907, *Conklin* 920 (SMS); Black River, Oct. 3, 1910, 1046 (SMS); Montreal River, Iron Co., Aug. 27, 1923, 1815 (SMS); Gurney Falls, Potato River, Sept. 7, 1925, 2557 (SMS); Loon Lake, Mellen, Ashland Co., Sept. 9, 1927, *Fassett & Wilson* (U).

34. *Lophozia ventricosa* (Dicks.) Dumort. Dells Wisconsin River, Sauk Co., Aug. 19, 1893, *L. M. Underwood* (NY & U); Bass Island, Ashland Co., Aug. 5, 1896, *Cheney* 5850 (U); Wilson Island, Aug. 6, 1896, 5895 (NY & U); Oak Island, Aug. 7, 1897, 6025 (U); Apostle Islands, Ashland Co., Aug. 1902, *Allen*, 31 B., 31 C., 31 A., 25 B., (U); Squaw Point, Bayfield Co., Aug. 10, 1917, *Conklin* 1293 p. p. (SMS); Orienta Falls, Sept. 23, 1923, 1931, 1917 (SMS); Herbster, July 27, 1923, 1961 A. (SMS).

35. *Sphenolobus exsectaeformis* (Breidl.) Steph. Lac Vieux Desert, Vilas Co., June 14, 1893, *Cheney* 82 p. p. (U); State Line, June 23, 1893, 631 (U); Houghton Quarries, Bayfield Co., July 28, 1896, 5552 (U); Apostle

Islands, Ashland Co., Aug. 1902, 31 C (U); Copper Creek, Douglas Co., May 5, 1909, *Conklin* 529 (SMS); Solon Springs, June 28, 1913, 1351 (SMS); Black River, April 18, 1915, 1349 (SMS); Stone's Bridge, June 12, 1916, 1347 (SMS); Squaw Point, Bayfield Co., Aug. 10, 1917, 1276, 1294 (SMS); Herbster, Bark Point, Aug. 27, 1923, 1851 p. p., 1851 (SMS).

36. *Sphenolobus exsectus* (Schmid.) Steph. Fayette, Lafayette Co., Dec. 1891, *Cheney* 30 (NY & U); Dells Wisconsin River, Sauk Co., Aug. 19, 1893, *L. M. Underwood* (NY & U); Coldwater Canon, Adams Co., July 30, 1894, *Cheney* 3823 (NY & U); Houghton Quarries, Bayfield Co., July 25, 1896, 5493 p. p. (U); Wilson Island, Ashland Co., Aug. 6, 1896, 5895 (U); Oak Island, Aug. 7, 1896, 6039 (U); Copper Creek, Douglas Co., Aug. 5, 1909, *Conklin* 599 (SMS); Black River, Oct. 2, 1910, 1000 (SMS); same location, Oct. 5, 1912, 1368, 1651, 1560 (SMS); Brule River, June 22, 1923, 1955 (SMS); Squaw Point, Bayfield Co., Aug. 10, 1919, 1282 (SMS); Siskiwit Point, Aug. 16, 1922, 1997 (SMS); Orienta Falls, Sept. 23, 1923, 1949 C (SMS); Mellen Ashland Co., Aug. 28, 1922, 2025 (SMS); Millville, Grant Co., Sept. 13, 1927, *Cheney* 12419 (U); Patch Grove, Sept. 24, 1927, 12464 p. p. (U).

37. *Sphenolobus hellerianus* (Nees) Steph. State Line, Vilas Co., June 23, 1893, *Cheney* 631, 636 (U); Tomahawk Lake, Oneida Co., June 29, 1893, 998 (U); Rainbow Rapids, July 4, 1893, 1263 (U); Granite Heights, Marathon Co., June 22, 1894, 2981, 2994, 2999 (NY & U); Drummond, Bayfield Co., June 29, 1896, 4376 p. p. (U); Mason, July 7, 1896, 4615 (NY & U); White River, July 8, 1896, 4632 p. p., 4635 (U); Frog Bay, Aug. 7, 1896, 6045 (U); Port Wing, July 12, 1897, 7185 p. p. (U); St. Louis River, Douglas Co., July 31, 1897, 7912 p. p. (U); Black River, Douglas Co., Oct. 5, 1912, *Conklin* 1573 (SMS); Solon Springs, June 28, 1913, 1348 (SMS); Mellen, Ashland Co., July 9, 1927, *Fassett & Wilson* (U).

38. *Sphenolobus michauxii* (Web.) Steph. State Line, Vilas Co., June 23, 1893, *Cheney* 636 (U); White River, Bayfield Co., July 8, 1896, 4633, 4635 (U); Frog Bay, Aug. 7, 1896, 6045 p. p. (U); Solon Springs, Douglas Co.,

July 30, 1911, *Conklin* 1109 (SMS); Mellen, Ashland Co., July 9, 1927, *Fassett & Wilson* (U).

39. *Sphenolobus scitulus* (Tayl.) Steph. Montreal River, Iron Co., Aug. 28, 1922, *Conklin* 1988, 2009 (SMS).

CEPHALOZIELLACEAE

1. *Cephaloziella bifida* (Schreb.) Schiffn. Bark Point, Bayfield Co., July 27, 1923, *Conklin* 1882 (SMS); Amnicon Falls, Douglas Co., Aug. 12, 1923, 1884 (SMS); Glen Haven, Grant Co., June 4, 1927 *Cheney* 12220 (U).

2. *Cephaloziella byssacea* (Roth) Warnst. Black River, Douglas Co., Oct. 3, 1913, *Conklin* 1252 A., 1253 (SMS); Solon Springs, Aug. 7, 1915, *Allen* 10 (U).

3. *Cephaloziella elachista* (Jack) Schiffn. Superior, Douglas Co., July 12, 1911, *Conklin* 1262 (SMS); Black River, Oct. 5, 1910, 1048, 1364 (SMS); Lake Nebagamon, June 1924, *L. R. Wilson* 426 (SMS); Amnicon Falls, July 13, 1924, *Conklin* 2239, 2238 (SMS).

4. *Cephaloziella hampeana* (Nees) Schiffn. Wilson Island, Ashland Co., Aug. 6, 1896, *Cheney* 5895 (U); Superior, Douglas Co., Sept. 12, 1909, *Conklin* 717, 716, 741, 739, 745 (SMS); Black River, Oct. 5, 1909, 621 (SMS); Orienta Falls, Bayfield Co., Sept. 23, 1923, 1935 (SMS); Gurney Falls, Iron Co., Sept. 7, 1925, 2576 (SMS).

5. *Cephaloziella myriantha* (Lindb.) Schiffn. Superior, Douglas Co., Sept. 12, 1909, *Conklin* 748 (SMS); Same location, Oct. 9, 1921, 1337 (SMS); Squaw Point, Bayfield Co., Aug. 26, 1922, 1779 (SMS).

6. *Cephaloziella sullivantii* (Aust.) Evans. Superior, Douglas Co., Sept. 12, 1909, *Conklin* 749 (SMS); Lake Nebagamon, Sept. 22, 1912, 1203 (SMS); St. Croix Lake, June 26, 1913, 1242 (SMS).

CEPHALOZIACEAE

1. *Cephalozia bicuspidata* (L.) Dumort. Fayette Lafayette Co., Dec. 1891, *Cheney* (NY); Mosinee, Marathon Co., June 28, 1894, 3308 (NY); Oak Island, Ashland Co., Aug. 7, 1896, 6023 p. p. (U); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 32 B, 62 (U); Superior, Douglas Co., July 5, 1909, *Conklin* 783 (SMS); Squaw Bay, Bayfield Co., Aug.

10, 1917, 1283 (SMS); same location, Oct. 8, 1927 3049 (SMS).

2. *Cephalozia catenulata* (Huben.) Spruce. Rainbow Rapids, Oneida Co., July 3, 1893, *Cheney* 1262 (U); Granite Heights, Marathon Co., June 28, 1894, 2954 (U); Coldwater Canon, Adams Co., July 30, 1894, 3814 p. p. (U); Opposite Fond du Lac, Douglas Co., July 28, 1897, 7753 (U); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 92 C. (U); Solon Springs, Douglas Co., Aug. 7, 1916, 36 (U); Black River, Douglas Co., Oct. 3, 1910, *Conklin* 1148 (SMS); Lake Nebagamon, July 13, 1913, 1228 (SMS).

3. *Cephalozia connivens* (Dicks.) Lindb. State Line, Vilas Co., June 21, 1893, *Cheney* 463 (U); Newbold, Oneida Co., July 8, 1893, 1531 (U); Gordon, Douglas Co., Aug. 25, 1907, *Conklin* 260 (SMS); Black River, Oct. 3, 1910, 1037 (SMS); Solon Springs, July 1, 1911, 1017 (SMS); Superior, July 1909, and Oct. 27, 1912, 767 (SMS); Lake Nebagamon, July 18, 1924, 1607 (SMS); Solon Springs, Summer 1925, *Conklin & Wilson,* 2418 (SMS); Solon Springs, Douglas Co., Aug. 5, 1915, *Allen* 54 (U).

4. *Cephalozia curvifolia* (Dicks.) Dumort. Dells Wisconsin River, Sauk Co., Aug. 19, 1893, *L. M. Underwood* (NY & U); Lac Vieux Desert, Vilas Co., June 20, 1893, *Cheney* 355 p. p. (U); Canover, June 24, 1893, 698 p. p. (U); Daugherty Lake, Oneida Co., July 3, 1893, 1281 (U); Rainbow Rapids, July 3, 1893, 1262, 1263 (U); Grandmother Bull Falls, Lincoln Co., July 27, 1893, 2288, 2297, 2359, 2356, 2357 (U); Granite Heights, Marathon Co., June 22, 1894, 2954, 2981, 2999 (U); Mosinee, June 28, 1894, 3308 (U); Coldwater Canon, Adams Co., July 30, 1894, 3814 (U); Drummond, Bayfield Co., June 29, 1896, 4376 p. p. (U); Mason, July 7 and 8, 1896, 4615, 4632 (U); White River at Mason, July 8, 1896, 4635 p. p., 4633 (U); Herbster, July 7, 1896, 6896 (U); Opposite Fond du Lac, Douglas Co., July 31, 1897, 7916 (U); same location, July 29, 1897, 7751 p. p. (U); Montreal River, Iron Co., July 22, 1896, 5244, (U); same location, July 31, 1896, 5175 (U); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 28 C., 79 C., 79 A., 64 B., 78 B., 79 B., 78 A., (U); Solon Springs, Douglas Co., Aug. 4 to 7, 1915, 12, 79, 49 (U); Sand Lake,

Sawyer Co., Aug. 28, 1925, (U) ; Bass Lake, Aug. 15, 1925, (U) ; Copper Creek, Douglas Co., Aug. 29, 1907, *Conklin* 270 (SMS) ; Solon Springs, May 1907, 408 (SMS) ; Black River, Oct. 5, 1912, 1570 (SMS) ; Lake Nebagamon, July 1, 1913, 1769 (SMS) ; Brule River, June 12, 1916, 2205 (SMS) ; Brule River, (Whealdon's), Sept. 28, 1925, 2489 (SMS) ; Loon Lake, Ashland Co., Sept. 8, 1927, *Fassett & Wilson* (U).

5. *Cephalozia macounii* Aust. Lac Vieux Desert, Vilas Co., June 13, 1893, *Cheney* 60 (NY & U) ; Newbold, Oneida Co., July 10, 1893, 1581 (U) ; Black River, Douglas Co., Oct. 3, 1911, *Conklin* 1148, 1153 (SMS) ; Lake Nebagoman, May 10, 1913, 1228, 1229 (SMS).

6. *Cephalozia media* Lindb. State Line, Vilas Co., June 21, 1893, *Cheney* 470 (NY & U) ; Tomahawk Lake, Oneida Co., June 28, 1893, 959, 952 (NY & U) ; Clear Lake, July 2, 1893, 1196 (NY & U) ; Rainbow Rapids, July 3, 1893, 1254, 1262, 1262 A., 1263, 1264 (U) ; Newbold, July 10, 1893, 1581 (NY & U) ; Grandmother Bull Falls, Lincoln Co., July 27, 1893, 2288 (U) ; Mosinee, Marathon Co., June 28, 1894, 3308 p. p. (U) ; Opposite Fond du Lac, Douglas Co., July 31, 1897, 7912, 7916 p. p. (U) ; Apostle Islands, Ashland Co., Aug. 1902, *Allen* 30 C. (U) ; Brule, Douglas Co., Aug. 13, 1915, 56 (U) ; Superior, Douglas Co., Sept. 12, 1909, *Conklin* 743 (SMS) ; Solon Springs, July 1, 1909, 1016 (SMS) ; Black River, July 28, 1913, 1355 (SMS) ; Lake Nebagamon, May 29, 1923, 1465 (SMS) ; Barron, Barron Co., March 31, 1927, *Cheney* 12092, 12097, 12101 p. p. 12108 p. p. (U) ; Mellen, Ashland Co., Sect. 16, July 9, 1927 *Fassett & Wilson* (U) ; Bad River Gorge, July 9, 1927, (U).

7. *Cephalozia pleniceps* (Aust.) Lindb. Tomahawk Lake, Oneida Co., June 23, 1893, *Cheney* 949 p. p., 933 p. p., 952 (U) ; Rainbow Rapids, July 3, 1893, 1253 (U) ; Newbold, July 8, 1893, 1531 p. p. (U) ; Montreal River, Iron Co., July 19, 1896, 5149 (NY & U) ; Opposite Fond du Lac, Douglas Co., July 31, 1897, 7911 (U) ; Solon Springs, Douglas Co., Aug. 5, 1915, *Allen* 19 (U) ; Brule River, Aug. 9, 1915, 34 (U) ; Superior, Douglas Co., July 15, 1909, *Conklin* 216 (SMS) ; Gordon, Oct. 25, 1909, 267 (SMS) ; Black River, Oct. 3, 1910, 1058 (SMS) ; Lake Nebagamon, June 1, 1913, 1770 (SMS) ; Brule River, June 12, 1916, 1412 (SMS) ;

Brule River, (Whealdon's), May 30, 1925, 2490 (SMS); Mud Creek, June 9, 1925, 2473 p. p. (SMS); Squaw Point, Bayfield Co., Aug. 26, 1922, 1837 (SMS); Siskiwit River, Oct. 5, 1924, (SMS); Barron, Barron Co., March 31, 1927, *Cheney* 12103 p. p. (U).

8. *Odontoschisma denudatum* (Mart.) Dumort. Lac Vieux Desert, Vilas Co., June 13, 1893, *Cheney* 59 (U); State Line, June 21, 1893, 470 (NY & U); Canover, June 24, 1893, 698, 729 (U); Rainbow Rapids, Oneida Co., July 3, 1893, 1254, 1264 p. p. (U); Drummond, Bayfield Co., June 29, 1896, 4376 p. p. (U); St. Louis River, Douglas Co., July 28, to 29, 1896, 7751, 7753 p. p. (U); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 92 C (U); Solon Springs, Douglas Co., Aug. 4, 1915, 21 (U); Solon Springs (Copeland Farm), Douglas Co., Oct. 7, 1907, *Conklin* 2162 (SMS); same location, July 20, 1911, 1685 (SMS); Stone's Bridge, Brule River, May 14, 1916, 1264 (SMS); Lake Nebagamon, Douglas Co., July 18, 1924, *Wilson* 2241 (SMS).

9. *Odontoschisma macounii* (Aust.) Underwood. Montreal River, Iron Co., Aug. 27, 1922, *Conklin* 1955 (SMS); Squaw Point, Bayfield Co., Oct. 8, 1927, 3032 (SMS).

10. *Calypogeia neesiana* (Massal. & Carest.) K. Mull. Tomahawk Lake, Oneida Co., June 28, 1893, *Cheney* 933 (U); Eagle River, June 28, 1893, 948, 951, 952, 949 (U); Winneboujou, Douglas Co., May 7, 1911, *Conklin* 1157 (SMS); St. Croix Lake, June 28, 1913, 1241 (SMS); Superior, Oct. 27, 1912, 1606 (SMS); Lake Nebagamon, July 11, 1913, 1773 (SMS); Stone's Bridge, Brule River, June 12, 1916, 2207 (SMS); Brule Swamp, St. Croix Lake, Douglas Co., Aug. 9, 1915, *Allen* 22, 34, 41, 55 (U); Barron, Barron Co., March 31, 1927, *Cheney* 12108, 12114 p. p., 12082, 12097 p. p., 12101, 12103 (U); Glen Haven, Grant Co., June 24, 1927, 12463 A. p. p. (U); Cornucopia, Bayfield Co., Oct. 8, 1927, *Conklin* 3051 (SMS).

11. *Calypogeia trichomanis* (L.) Corda. Coldwater Canon, Adams Co., July 30, 1894, *Cheney* 3814 (U); Solon Springs, Douglas Co., Sept. 16, 1906, *Conklin* 289 (SMS); Copper Creek, Aug. 5, 1909, 531 (SMS); Superior, Sept. 2, 1909, 489 (SMS); same location, Nov 14, 1909, 609 (SMS); Black River, Oct. 2, 1910, 1062 (SMS); Mellen, Ashland Co., July 9, 1927, *Fassett & Wilson* (U).

12. *Bazzania trilobata* (L.) S. F. Gray. Penokee Iron Range, Ashland Co., Sept. 1858, *I. A. Lapham* (U); Lac Vieux Desert, Vilas Co., June 13, 1893, *Cheney* 54 (U); same location, June 14, 1893, 86 (U); June 22, 1893, 575 (U); Canover and Eagle Rivers, June 26, 1893, 826 (U); Rainbow Rapids, Oneida Co., July 4, 1893, 1318 (U); Merrill, Lincoln Co., July 31, 1893, 2715 (U); Granite Heights, Marathon Co., June 23, 1894, 3150 (U); White River, Bayfield Co., July 8, 1896, 4624, 4628 (U); Sand Bay, June 22, 1897, 6314 (U); Bark Point, July 3, 1897, 6737 (U); Wilson Island, Ashland Co., Aug. 6, 1896, 5909 (U); Brule River, Douglas Co., July 19, 1897, 7501 (U); Opposite Fond du Lac, July 31, 1897, 7948 (U); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 18, 21, 52 (U); Bass Lake, Sawyer Co., Aug. 15, 1925, (U); Solon Springs, Douglas Co., Aug. 26, 1906, *Conklin* 160 (SMS); Gordon, Sept. 15, 1906, 318 (SMS); Copper Creek, Aug. 5, 1909, 565 (SMS); Superior, June 3, 1909, (SMS); Brule River, April 9, 1910, 1031 (SMS); Lake Nebagamon, June 1, 1913, 1771 (SMS); Winneboujou, May 1, 1925, 2497 (SMS); Cussen, Bayfield Co., June 25, 1913, 1356 (SMS); Drummond, Aug. 23, 1925, 2630 (SMS); Barron, Barron Co., March 31, 1927, *Cheney* 12109, 12112, 12116 (U); Mellen, Ashland Co., Sept. 16, *Fassett & Wilson,* July 9, 1927, (U);

13. *Lepidozia reptans* (L.) Dumort. Fayette, Lafayette Co., Dec. 1198, *Cheney* 37 (NY); Lac Vieux Desert, Vilas Co., June 13, 1893, 10, 49 (U); same location, June 14, 1893, 82 p. p., 86 (U); State Line, June 23, 1893, 629 (NY & U); Canover, June 26, 1893, 825 p. p. (NY & U); Tomahawk Lake, Oneida Co., June 28, 1893, 952 (NY & U); Rainbow Rapids, June 29, 1893, 1021 (NY & U); same location, July 3, 1893, 1264 p. p. (U); Newbold, July 8, 1893, 1520 (U); same location, July 10, 1893, 1581 (U); Grandmother Bull Falls, Lincoln Co., July 26, 1893, 2275, (U); Drummond, Bayfield Co., June 26, 1896, 4392 (U); Mason, July 6, 1896, 4601 (U); White River, July 8, 1896, 4646 (U); Montreal River, Iron Co., June 19, 1896, 5040 (U); same location, July 20, 1896, 5148 (U); Wilson Island, Ashland Co., Aug. 6, 1896, 5910 (U); St. Louis River, Douglas Co., July 31, 1897, 7910 (U); Appostle Islands, Ashland Co., Aug. 1902,

Allen 31 B., 43 A., 14 B., 42 B., 14 A., (U); Solon Springs, Douglas Co., Aug. 4 to 9, 1915, 35, 60 B. (U); Copper Creek, Douglas Co., Aug. 5, 1909, *Conklin* 544 (SMS); Superior, July 5, 1909, 611 (SMS); Black River, Oct. 3, 1909, 1056 (SMS); Lake Nebagamon, Sept. 3, 1911, 1149 p. p. (SMS); Stone's Bridge, Brule River, June 12, 1916, 1415 (SMS); Brule River, (Whealdon's), May 1, 1925, 2495 (SMS); Squaw Point, Bayfield Co., June 12, 1917, 1292 (SMS); Orienta Falls, Sept. 23, 1923, 1951 (SMS); Herbster, June 23, 1923, 1961 (SMS); Siskiwit Point, Oct. 5, 1924, 2373 (SMS); Montreal River, Iron Co., Sept. 6, 1925, (SMS); Barron, Barron Co., March 31, 1927, *Cheney* 12114 (U); Patch Grove, Grant Co., Sept., 24, 1927, 12463 A., 12464 p. p. (U).

PTILIDIACEAE

1. *Ptilidium ciliare* (L.) Nees. Milwaukee, Milwaukee Co., July 1862 (U); Lac Vieux Desert, Vilas Co., June 13, 1893, *Cheney* 47 (U); Tomahawk, Lincoln Co., July 21, 1893, 2127 (U); Copper Creek, Douglas Co., Aug. 5, 1909, *Conklin* 588 (SMS); Black River, Oct. 5, 1909, 613 (SMS). Black River, Oct. 5, 1909, 613 (SMS).

2. *Ptilidium pulcherrium* (Web.) Hampe. Milwaukee, Milwaukee Co., July 1862, *I. A. Lapham* (U); Fayette, Lafayette Co., Dec. 1891, *Cheney* 10, 19, 31, 38, (NY); Lake Mills, Jefferson Co., March 30, 1891, "O" (U); Middleton, Dane Co., Oct. 21, 1892, *Cheney & True* (U); Lac Vieux Desert, Vilas Co., June 13, 1893, *Cheney* 15, 20, 25, 47, 48 (U); same location, June 14, 1893, 89 (U); June 1893, 561 (NY); Canover, June 24, 1893, 725 (NY & U); Newbold, Oneida Co., July 10, 1893, 1560, 1757 p. p. (NY. & U); Whirlpool Rapids, July 19, 1893, 6817 (U); Tomahawk Lake, Oneida & Lincoln Cos., July 21, 1893, 2116 (U); Tomahawk, Lincoln Co., July 25, 1893, 2192, 2194 (U); Grandmother Bull Falls, July 26, 1893, 2320 (NY. & U); Granite Heights, Marathon Co., June 23, 1894, 2981, 2994, 2998, 2999 (U); Mason, Bayfield Co., July 7, 1896, 4615 p. p. (U); White River, July 8, 1896, 4635, 4639 (U); Drummond, July 22, 1896, 4157 (U); Siskiwit Bay, June 29, 1897, 6575 (U); Port Wing, July 12, 1897, 7185 (U);

Orienta, July 15, 1897, 7356 (U); Herbster, July 7, 1897, 6928 A., 6932, (U); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 1, 9, 12 A., 13, 19, 20, 31 C., 51, 79 A., 90, 91 B., 51 B. (U); Solon Springs, Douglas Co., Aug. 4 to 7, 1915, 8, 10, 13, 30, 44, 60 A., 65, 68 (U); Solen Springs, Douglas Co., Aug. 26, 1906, *Conklin* 166 (SMS); Gordon, Sept. 15, 1906, 917 (SMS); Superior, Sept. 12, 1909, 730 (SMS); Lake Nebagamon, Sept. 3, 1911, 1153 p. p. (SMS); Brule River, April 15, 1912, 1007 (SMS); Head St. Croix Lake, June 29, 1924, 2230 (SMS); Squaw Point, Bayfield Co., Aug. 10, 1917, 1335 (SMS); Siskiwit Point, Aug. 26, 1922, 1995 (SMS); Bark Point, July 27, 1923, 1878 (SMS); Mt. Hope, Grant Co., Oct. 15, 1927, *Cheney* 12519, 12520 (U); Barron, Barron Co., April 13, 1926, 11113 (U); same location, April 2, 1927, 12130 (U); Mellen, Ashland Co., Sept. 16, Sept. 4, 1927, *Fassett & Wilson* (U); St. Croix Falls, Polk Co., Sept, 4, 1927, p. p. (U); Loon Lake, Ashland Co., Sept. 8, 1927, (U); Clinton, Rock Co., July 16, 1928, *Cheney* 12603 (U).

3. *Blepharostoma trichophyllum* (L.) Dumort. Fayette, Lafayette Co., Dec. 1891, *Cheney* 35, 39 (NY); State Line, Vilas Co., June 21, 1893, 469 p. p., 470 p. p. (NY & U); Lac Vieux Desert, June 22, 1893, 576 (NY & U); same location, June 23, 1893, 636 p. p. (NY & U); Rainbow Rapids, Oneida Co., July 4, 1893, 1264 (NY & U); Newbold, July 8, 1893, 1522 (NY & U); Montreal River, Iron Co., July 19, 1896, 5040 p. p. (NY & U); Shore of Lake Superior, July 21, 1896, 5175 p. p. (NY & U); Oak Island, Ashland Co., Aug. 7, 1896, 5992, 6023 p. p. (NY & U); Drummond, Bayfield Co., June 29, 1896, 4376 p. p. (NY & U); Herbster, July 7, 1897, 6907 p. p., 6946 (U); Port Wing, July 8, 1897, 7017 p. p. (U); same location, July 12, 1897, 7197, (NY); Orienta, July 14, 1897, 7278, 7274 (NY); Copper Creek, Douglas Co., *Conklin,* Aug. 5, 1909, 595 (SMS); Superior Sept. 12, 1912, 734 (SMS); Winneboujou, April 20, 1911, 1028 (SMS); Black River, Oct. 5, 1912, 1225 (SMS); Brule River, June 12, 1916, 1419 (SMS); Squaw Bay, Bayfield Co., Aug. 10, 1917, 1280 (SMS); Bark Point, July 27 1923, 1957 (SMS); Siskiwit River, Sept. 1, 1923, 1874 (SMS); Montreal River, Iron Co., Aug. 27, 1923, 1832 (SMS); same

location, Sept. 6, 1925, 2558 (SMS); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 29 B., 27 A., 30 A., 42 B., 30 B., 30C., 22 A., 27 C., (U).

4. *Trichocolea tomentella* (Ehrh.) Dumort. Rainbow Rapids, Oneida Co., July 1, 1893, *Cheney* 1165, 1168 (NY & U); Coldwater Canon, Adams Co., July 30, 1894, 3817 (U); Montreal River, Iron Co., July 21, 1896, 5165 (U); St. Louis River, Douglas Co., July 31, 1897, 7949 (U); Winneboujou, Douglas Co., May 20, 1911, *Conklin* 1198 (SMS); Brule River, June 12, 1916, 2197 (SMS); Hall's Swamp, Brule River, May 1, 1925, 2498 (SMS); Barron, Barron Co., March 31, 1927, *Cheney* 12079 (U); Mellen, Ashland Co., July 9, 1927, *Fassett & Wilson* (U).

SCAPANIACEAE

1. *Diplophyllum apiculatum* (Evans) Steph. Orienta Falls, Bayfield Co., Sept. 23, 1923, *Conklin* 1941 (SMS).

2. *Diplophyllum gymnostomophilum* Kaal. Black River, Douglas Co., Oct. 5, 1912, *Conklin* 959, 1361, 1527, 1591 (SMS); Gurney Falls, Potato River, Iron Co., Sept. 7, 1925, 2576 (SMS).

3. *Scapania apiculata* Spruce. Cranberry River, Bayfield Co., July 7, 1897, *Cheney* 6882 p. p. (U); Herbster, July 8, 1897, 7008 (U); St. Louis River, Douglas Co., July 31, 1897, 7955 (U); St. Louis Bay, Superior, Douglas Co., Aug. 1905, *Conklin* 382 (SMS); Copper Creek, Aug. 5, 1909, 530 (SMS); Wentworth, Oct. 19, 1910, 1004 (SMS); Black River, Oct. 5, 1912, 1573, 1625 (SMS); Stone's Bridge, Brule River, July 12, 1916, 2223 (SMS); Squaw Point, Bayfield Co., Oct. 8, 1927, 3049, 3050 (SMS).

4. *Scapania cuspiduligera* (Nees) K. Mull. Squaw Point, Bayfield Co., Aug. 10, 1917, *Conklin* 1301 (SMS); same location, Aug. 26, 1922, 1788 (SMS); Bark Point, Aug. 3, 1924, 2277 (SMS); Squaw Point, Oct. 4, 1924, 2361, 2429 (SMS).

5. *Scapania curta* (Mart.) Dumort. Montreal River, Iron Co., July 10, 1896, *Cheney* 5115 (NY & U); Houghton Quarries, Bayfield Co., July 25, 1896, 5444, 5493 (NY & U); Oak Island, Ashland Co., Aug. 7, 1896, 6033 (NY & U); Copper Creek, Douglas Co., Oct. 1907, *Conklin* 390 (SMS);

Superior, Sept. 12, 1909, 738, 745 (SMS); Black River, Oct. 5, 1909, 635, 1074 (SMS); Squaw Point, Bayfield Co., Aug. 10, 1917, 1283, 1284, 1279, 1295, 1320, 1219, 1297 p. p., 1297 (SMS); same location, Aug. 25, 1924, 1783 (SMS); Oct. 4, 1924, 2385, 2435 (SMS); Siskiwit Point, July 29, 1923, 1886 (SMS); same location, Sept. 1, 1923, 1909 (SMS); Orienta Falls, Sept. 23, 1923, 1934, 1847 (SMS); Herbster, July 27, 1923, 1960 (SMS); Montreal River, Iron Co., Aug. 28, 1922, 1811, (SMS); Mellen, Ashland Co., Aug. 29, 1922, 1792 p. p. (SMS); Patch Grove, Grant Co., Sept. 24, 1927, *Cheney* 12464 (U); Mellen, Ashland Co., Sept. 7, 1927, *Fassett & Wilson* (U).

(Dr. H. Büch, of Helsingfors, Finland has recently studied *S. curta* and has split the composite species *S. curta* into several species. Some of these specimens in Wisconsin he has referred to his new *S. mucronata* Büch. The only specimen from Wisconsin sent him by Dr. A. W. Evans, which he referred to *S. curta* was No. 1079, (duplicate of 1074 above.) Until Dr. Büch's monograph is available for study all specimens are referred under *S. curta* in this report (G. H. C.).

6. *Scapania dentata* Dumort. Squaw Point, Bayfield Co., July 29, 1923, *Conklin* 1848 (SMS); Siskiwit Point, Oct. 5, 1924, 2362, 2442 (SMS).

7. *Scapania glaucocephala* (Tayl.) Aust. Lake Superior, near Montreal River, Iron Co., July 21, 1896, *Cheney* 5191 (NY & U); Solon Springs, Douglas Co., Aug. 7, 1915, *Allen* 11 (U); Black River, Douglas Co., Oct. 5, 1909, *Conklin* 620 (SMS); same location, Oct. 5, 1912, 1365 (SMS); Solon Springs, Aug. 6, 1911, 1112 (SMS); Cussen, Bayfield Co., July 25, 1915, 1244 (SMS); Brule River, (Whealdon's) Douglas Co., Aug. 24, 1924, *Wilson* 2282 (SMS).

8. *Scapania irrigua* (Nees) Dumort. Superior, Douglas Co., Oct. 20, 1908, *Conklin* 1019 (SMS); same location, Sept. 12, 1909, 735, 741 (SMS); Brule River, Stone's Bridge, June 12, 1916, 1415 (SMS); Mud Creek, June 8, 1925, 2472 (SMS); Lake Nebagamon, Douglas Co., June 1924, *Nancy Bond* (SMS); Mellen, Ashland Co., July 9, 1927, *Fassett & Wilson* (U); Siskiwit Point, Bayfield Co., Oct. 9, 1927, *Conklin* 3051 (SMS);

9. *Scapania nemorosa* (L.) Dumort. Mosinee, Marathon Co., July 29, 1894, *Cheney* 3320, 3308 (NY & U); Coldwater Canon, Adams Co., July 30, 1894, 3814 p. p. (NY & U); Witch's Gulch, July 30, 1894, 3897 (U); Oak Island, Ashland Co., Aug. 7, 1926, 6033 p. p., 6039 (U); Devils Lake, Sauk Co., Aug. 16, 1917, *Allen* 28 (U); Black River, Douglas Co., Oct. 5, 1909, *Conklin* 643 (SMS); Amnicon Falls, Oct. 1, 1922, 1741 (SMS); Squaw Point, Bayfield Co., Aug. 10, 1917, 1318 (SMS); same location, Aug. 27, 1923, 1836 (SMS); Siskiwit Point, July 29, 1923, 1885 (SMS); Orienta Falls, Sept. 23, 1923, 1938 (SMS); Bagley, Grant Co., June 24, 1927, *Cheney* 12310, 12311 (U); Mellen, Ashland Co., Sept. 8, 1927, *Fassett & Wilson* (U);

10. *Scapania paludicola* Loeske & K. Mull. Drummond, Bayfield Co., June 29, 1896, *Cheney* 4376 p. p., 4377 (NY & U); Lac Vieux Desert, Vilas Co., Aug. 29, 1917, *Allen* 58 (U); Black River, Douglas Co., Oct. 3, 1910, *Conklin* 1009 (SMS); same location, Oct. 21, 1915, 1251, 1258 p. p (SMS); Amnicon Lake, July 13, 1924, 2237 (SMS).

11. *Scapania subalpina* (Nees) Dumort. Montreal River, Iron Co., July 20, 1896, *Cheney* 5115 p. p. (U); Oak Island, Ashland Co., Aug. 7, 1896, 6033 p. p. (U); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 27 B, 29 B, 30 A, 32 A, 32 B, 32, 33, 34, 35 B, 72, 73 (U); Black River, Douglas Co., Oct. 5, 1912, *Conklin* 1206 (SMS); Squaw Point, Bayfield Co., Aug. 10, 1917, 1281, 1316, 1297 p. p. (SMS); same location, July 29, 1923, 1986 (SMS); Squaw Bay, Aug. 26, 1922, 1814, 1916 (SMS); Siskiwit Point, July 29, 1923, 1892, 1864 (SMS); Orienta Falls, Sept. 23, 1893, 1937 (SMS); Herbster, Aug. 27, 1923, 1851 (SMS); Montreal River, Iron Co., Sept. 6, 1925, 2549 (U).

12. *Scapania undulata* (L.) Dumort. Squaw Point, Bayfield Co., Aug. 10, 1919, *Conklin* 1317 (SMS).

RADULACEAE

1. *Radula complanata* (L.) Dumort. Rainbow Rapids, Oneida Co., June 29, 1893, *Cheney* 1026 (NY & U); Grandmother Bull Falls, Lincoln Co., July 29, 1893, 2663 (NY & U); White River, Bayfield Co., July 8, 1896, 4651 (U); Devils Lake, Sauk Co., July 11, 1903, *(collector unrecorded)*

(U); Gordon, Douglas Co., Sept. 10, 1906 *Conklin* 156 (SMS); Copper Creek, Aug. 5, 1909, 573 (SMS); Black River, Oct. 3, 1910, 1226 (SMS); Brule River, July 22, 1923, 1902 (SMS); Lyman Lake, Aug. 20, 1923, 1870 (SMS); Siskiwit Point, Bayfield Co., July 29, 1923, 1887 (SMS); Montreal River, Iron Co., Sept. 6, 1925, 2552 (SMS); Bad River Gorge, Ashland Co., Sept. 8, 1927, *Fassett & Wilson* (U); Wapogasset, Polk Co., Aug. 31, 1927, *Allen* (U); St. Croix Falls, Polk Co., June 6, 1927, *Mary Van Wert, H.* 37 p. p. (SMS).

2. *Radula obconica* Sullivant. Goodrich to Granite Heights, Marathon Co., June 25, 1894, *Cheney* 3192 (U); White River, Bayfield Co., July 8, 1896, 4629, 4651, 4651 p. p. (U); Herbster, July 7, 1897, 6893 (U); Wentworth, Douglas Co., Oct. 19, 1910, *Conklin* 963 (SMS); Stone's Bridge, June 12, 1916, 2204 (SMS); Brule River, July 22, 1923, 1965 (SMS); Squaw Point, Bayfield Co., Aug. 10, 1917, 1334 (SMS); Cornucopia, April 29, 1923, 1996 (SMS); Barron, Barron Co., March 31, 1927, *Cheney* 12102, 12111 (U); Mellen, Ashland Co., Sect. 16, Sept. 7, 1927, *Fassett & Wilson* (U); Bad River Gorge, Sept. 8, 1927, (U).

PORELLACEAE

1. *Porella pinnata* L. Wisconsin River, Oneida Co., July 19, 1893, *Cheney* 1837, 1839 (U); Granite Heights, Marathon Co., June 22, 1894, 2958 (NY & U); Witch's Gulch, Adams Co., July 31, 1894, 3883 (NY & U); St. Croix Falls, Polk Co., July 14, 1890, *H.* (UM).

2. *Porella platyphylla* (L.) Lindb. Penokee, Iron Range, Ashland Co., *I. A. Lapham* (U); Madison, Dane Co., April 1886, *A. B. Seymour* (NY); Trempealeau Co., May 17, 1890, *H* (NY); Baraboo, Sauk Co., May 1, 1891, *True* 9, 12, (NY); Vilas Woods, Dane Co., May 3, 1902, *(No collectors given)*, (U); Devils Lake, Sauk Co., July 11, 1903, (U); Eagle Heights, Dane Co., April 22, 1902, (U); Blue Mounds, Iowa Co., Aug. 1, 1903, (U); Northern Wisconsin, April 1907, *J. F. Brenckle* 1100, 1097 (SMS); Madison, Dane Co., Aug. 25, 1890, *Cheney* (NY); Fayette, Lafayette Co., Dec. 1891, 24, 26, 27, 43 (NY); Lac Vieux Desert, Vilas

Co., June 20, 1893, 344 (NY & U); Drummond, Bayfield Co., June 24, 1896, 4179 (U); Houghton Quarries, July 25, 1896, 5705 (U); Solon Springs, Douglas Co., Sept. 5, 1915, *Allen* 61 (U); Apostle Islands, Ashland Co., Aug. 1902, 17 (U); Bass Lake, Sawyer Co., Aug. 15, 1925, (U); Parfrey's Glen, Sauk Co., May 23, 1926, (U); Gordon, Douglas Co., Sept. 15, 1906, *Conklin* 329 (SMS); Solon Springs, May 1907, 1023 (SMS); Superior, Dec. 27, 1908, 324 (SMS); Copper Creek, Aug. 5, 1909, 534 (SMS); Black River, Oct. 3, 1910, 1068 (SMS); Lake Nebagamon, Sept. 3, 1911, 1149 p. p., 1146 (SMS); Amnicon Lake, May 6, 1923, 1754 (SMS); Lyman Lake, Aug. 20, 1923, 1872 (SMS); Cornucopia, Bayfield Co., Aug. 26, 1922, 1996 (SMS); Solon Springs, Douglas Co., June 22, 1924, *Wilson* 2360 (SMS); Potosi, Grant Co., May 4, 1926, *Cheney* 11163 (U); same location, May 19, 1926, 11296 (U); Barron, Barron Co., March 31, 1927, 12106 (U); Glen Haven, Grant Co., June 10, 1927, 12258 (U); same location, May 18, 1927, 12181 (U); Turvip Rock, Trempealeau Co., May 17, 1890, *H* (UM); Insor Creek, May 17, 1890, (UM); Lake Wapogasset, Polk Co., Aug. 31 and Sept. 4, 1927, *Allen* (U); Turtle Lake, Rock Co., July 7, 1928, *Cheney* 12755, 12757, 12756 (U); Bradford Tp., July 31, 1928, 12723 (U).

3. *Porella platyphylloidea* (Schwein.) Lindb. Madison, Dane Co., Dec. 19, 1891, *Cheney & True* (U); Madison, Dane Co., July 8, 1903, (*No collector given*), (U); Madison, Dane Co., *I. C. Carr* (U); Rainbow Rapids, Oneida Co., July 4, 1893, *Cheney* 1327, 1325 (NY & U); Montreal River, Iron Co., July 21, 1896, 5166, 5195 (U); La Pointe, Madeline Island, Ashland Co., July 30, 1896, 5705 (U); Drummond, Bayfield Co., June 24, 1896, 4164 (U); Mason, July 8, 1896, 4545 (U); Herbster, July 5, 1897, 6823, 6892 (U); Port Wing, July 8, 1897, 7032 (U); same location, July 12, 1897, 7186 (U); Arena, Iowa Co., Sept. 3, 1922, *Allen* (U); Green Lake, Green Co., July 16, 1922, (U); Gordon, Douglas Co., Sept. 15, 1902, Conklin 157, 329 (SMS); St. Croix Falls, Polk Co., Aug. 7, 1925, 2485 (SMS); Lodi, Columbia Co., Oct. 4, 1926, *Wilson* 4 (SMS); Barron, Barron Co., Sept. 1, 1925, *Cheney* 9761 (U); same location, March 31, 1927, 12111 p. p. (U); Newark Tp., Rock Co., Aug. 30, 1928, *Cheney* 12810 (U).

LEJEUNEACEAE

1. *Lejeunea cavifolia* (Ehrh.) Lindb. Grandmother Bull Falls, Lincoln Co., July 29, 1893, *Cheney* 2497, 2558 (NY & U); Montreal River, Iron Co., Aug. 27, 1922, *Conklin* 1801 (SMS).

2. *Cololejeunea biddlecomiae* (Aust.) Evans. Mason, Bayfield Co., July 7, 1896, *Cheney* 4645 (NY & U); Copper Creek, Douglas Co., Aug. 5, 1909, *Conklin* 384, 569 (SMS); Black River, Oct. 3, 1910, 1055 (SMS); St. Croix Lake, June 28, 1913, 1339 (SMS); Amnicon Falls, Aug. 12, 1922, 1868 (SMS); Cornucopia, Bayfield Co., Aug. 26, 1922, 1999 (SMS); Montreal River, Iron Co., Sept. 26, 1925, 2554 (SMS).

3. *Frullania asagrayana* Mont. Rainbow Rapids, Oneida Co., July 4, 1893, *Cheney* 1314 (U); Grandmother Bull Falls, Lincoln Co., July 27, 1893, 2353, 2365 (U); Granite Heights, Marathon Co., June 22, 1894, 2964, 2995 (U); Montreal River, Iron Co., July 19, 1896, 5044 (U); Odanah Indian Reservation, July 22, 1896, 5235, 5238 (U); Fayette, Lafayette Co., Dec. 1899, 532 (NY & U); Potosi, Grant Co., May 29, 1926, 11388 (U); Mt. Hope, Oct. 15, 1927, 12521 (U); Stone's Bridge, Brule River, Douglas Co., June 27, 1926, *Conklin* 2646 (SMS); Mellen, Ashland Co., Sect. 16, July 9, 1927, *Fassett & Wilson* (U).

4. *Frullania bolanderi Aust.* Lake Nebagamon, Douglas Co., Sept. 3, 1911, *Conklin* 1117 (SMS); Amnicon Lake, May 6, 1923, 1753 (SMS).

5. *Frullania brittoniae* Evans. Madison, Dane Co., Dec. 19, 1891, *Cheney & True* (U); same location, Dec. 1899, 28 (NY & U); Grandmother Bull Falls, Lincoln Co., July 27, 1893, *Cheney* 2347 (U); Mason, Bayfield Co., July 6, 1896, 4558 (NY & U); Herbster, July 7, 1897, 6928 (U); Amnicon River, Douglas Co., July 20, 1897, 7558 (U); Gordon, Douglas Co., Sept. 15, 1906, *Conklin* 351, 362 (SMS); Solon Springs, Oct. 7, 1907, 362, 481 (SMS); Lake Nebagamon, Sept. 3, 1911, 1148 (SMS); Barron, Barron Co., March 31, 1927, *Cheney* 12094, 12113 (U); Glen Haven, Grant Co., May 16, 1927, 12166 (U); same location, May 18, 1927, 12179 (U); Bagley, Grant Co., May 30, 1927, 12203 (U);

Bradford Tp., Rock Co., July 2, 1928, *Cheney* 12728 (U); same location, July 27, 1928, 12713 (U), Aug. 8, 1928, 12761 (U); Clinton, Sept. 11, 1928, 12784 (U); Afton, Oct. 26, 1928, 12870 (U).

6. *Frullania eboracensis* Gottsche. Madison, Dane Co., Dec. 9, 1891, *Cheney & True* (U); Madison, Dane Co., Dec. 1891, *Cheney* 20 A, 20 B, 22 (NY & U); Fayette, Lafayette Co., Dec. 1891, 2, 4, 20, 21, 25, 33, 34, 41, (NY & U); Lac Vieux Desert, Vilas Co., June 13, 1893, 1 (U); same location, June 20, 1893, 35, 320, 325, 342 (U); Rhinelander, Oneida Co., July 18, 1893, 1819 (U); Rainbow Rapids, July 3, 1893, 1265 (U); Grandmother Bull Falls, Lincoln Co., July 26, 1893, 2276, 2268 (U); same location, July 27, 1893, 2437 (NY & U); Montreal River, Iron Co., July 20, 1896, 5127 (NY & U); Wilson Island, Ashland Co., Aug. 6, 1896, 5925 (U); Drummond, Bayfield Co., June 24, 1896, 4184 (U); Bark Point, July 5, 1897, 6732 (U); Herbster, July 7, 1897, 6902 (U); Cranberry River, July 7, 1897, 6936 (U); Amnicon River, Douglas Co., July 30, 1897, 7758 p. p. (U); St. Louis River, July 28, 1897, 7786 (U); Devils Lake, Sauk Co., July 11, 1903, *(No collectors given)*, (U); Blue Mounds, Iowa Co., Aug. 1, 1903, (U); Apostle Islands, Ashland Co., Aug. 1902, *Allen* 89 (U); Arena, Iowa Co., Sept. 2, 1922, (U); Gordon, Douglas Co., Sept. 15, 1906, *Conklin* 366 (SMS); Copper Creek, Sept. 1, 1907, 506 (SMS); Black River, Oct. 5, 1909, 629 (SMS); Superior, Aug. 1911, 348 (SMS); Lake Nebagamon, Sept. 3, 1911, 1153 (SMS); Lyman Lake, Aug. 20, 1923, 1871 (SMS); Siskiwit Point, Bayfield Co., Aug. 26, 1922, 1994 (SMS); Montreal River, Iron Co., Sept. 26, 1925, 2555 (SMS); Solon Springs, Douglas Co., June 29, 1924, *Wilson* 2228 (SMS); Barron, Barron Co., March 31, 1927, *Cheney* 12087, 12089, 12090, 12091, 12118, 12083, 12084, 12085, 12086 (U); same location, April 1, 1925, 9720 (U); Glen Haven, Grant Co., May 16, 1927, 12165, 12167, 12169 (U); Bagley, June 3, 1927, 12224 (U); St. Croix Falls, Polk Co., July 12, 1890, *H* (UM); Trempealeau Mt., Trempealeau Co., July 31, 1890, (UM); Bad River Gorge, Ashland Co., Sept. 8, 1927, *Fassett & Wilson* (U); Wapogasset, Polk Co., Sept. 3, 1927, *Allen* (U); Bear Trap Lake, Sept. 8, 1927, (U); Midland,

Buffalo Co., June 1903, *H.* (UM). Clinton, Rock Co., July 20, 1928, *Cheney* 12609 (U); same location, July 25, 1928, 1225 (U), July 26, 1928, 12626 (U); Bradford Tp., Aug. 8, 1928, 12762 (U); Avon, Aug. 19, 1928, 12795, 12797, 12796 (U); Newark Tp., Oct. 13, 1928, 12841 (U); same location, Oct. 18, 1928, 12844, 12846, 12847 (U).

7. *Frullania inflata Lehm. & Lindenb.* Stevens Point, Portage Co., June 30, 1894, *Cheney* 3358 (U); Herbster, Bayfield Co., July 4, 1897, 6878 (U); Bridgeport, Grant Co., July 19, 1927, 12345 (U); Bridgeport, Grant Co., July 19, 1927, *Cheney* 12345 (U).

8. *Frullania selwyniana* Pears. St. Croix Lake, Solon Springs, Douglas Co., Jan. 28, 1913, *Conklin* 1239 (SMS); Stone's Bridge, Brule River, May 30, 1925, 1417 (SMS).

9. *Frullania riparia* Hampe. Potosi, Grant Co., May 2, 1926, *Cheney* 11155, 11342 (U); same location, May 4, 1926, 11162, 11164 (U); May 6, 1926, 11186 (U); May 10, 1926, 11222 (U); May 26, 11342 (U); Glen Haven, Grant Co., Aug. 2, 1926, 11575, 11576 (U); same location, Aug. 21, 1926, 11690 (U); May 18, 1927, 12180, 12182 (U); Bagley, June 3, 1927, 12225, 12226 (U); same location, June 16, 1927, 12273 (U); Millville, Sept. 13, 1927, 12420 (U); St. Croix Falls, Polk Co., July 12, 1890 *H.* (UM); Turtle Lake, Rock Co., July 7, 1928, *Cheney* 12759 (U); same location, July 24, 1928, 12703 (U).

10. *Frullania oakesiana* Aust. Wentworth, Douglas Co., Oct. 19, 1910, *Conklin* 2155 (SMS).

ANTHOCEROTALES

ANTHROCEROTACEAE

1. *Notothylas orbicularis* (Schwein.) Sullivant. Madison, Dane Co., Aug. 10, 1892, *Cheney & True.*

2. *Anthoceros laevis* L. Marshland, Buffalo Co., Aug. 18, 1890, *H.* (NY & SMS); Madison, Dane Co., Oct. 8, 1892, *Cheney & True* (U); Dells Wisconsin River, Sauk Co., American Association for the Advancement of Science Meeting, Aug. 19, 1893, (U); Argyle, Lafayette Co., Aug. 6, 1892, *Cheney* (U); Merrill, Lincoln Co., July 31, 1893, 2725

(U); same location, Aug. 1, 1893, 2822 (U); Petanwells and Germantown, Adams & Juneau Cos., July 19, 1894, 3704 (U); Coldwater Canon, Aug. 1, 1894, 3916 (U); Superior, Douglas Co., Oct. 1904, *Conklin* 79 (SMS); Black River, Manitou Falls, Oct. 1906, 459 (SMS); Brule River, Oct. 7, 1923, 2011 (SMS); Montreal River, Iron Co., Aug. 27, 1922, 1803 (SMS); Cornucopia, Bayfield Co., Aug. 16, 1916, 2371 (SMS); Maiden Rock, Pierce Co., Aug. 16, 1916, *Allen* 43 (U); Messinger Springs, Sauk Co., Aug. 16, 1917, 9 (U); Trempealeau Mt., Trempealeau Co., May 17, 1890, *H.* (U); Cassville, Grant Co., July 7, 1927, *Cheney* 12337 (U); Bagley, May 30, 1927, 12204 (U); Wapogasset, Polk Co., Aug. 28, 1927, *Allen* (U); Dodge, Trempealeau Co., June 21, 1902, *H.* (UM); Trempealeau Mt., Trempealeau Co., Nov. 11, 1893 *H.* (det. L. M. Underwood). (Specimen not seen. Reported XXVI. Bull. No. 9 Holzenger. Nat. Hist. Survey of Minn.)

3. *Anthoceros macounii* M. A. Howe. Grandmother Bull Falls, Lincoln Co., July 26, 1893, *Cheney* 2265 (U).

4. *Anthoceros punctatus* L. Arena, Iowa Co., Sept. 2, 1922, *Allen* 12 (U).

In the following pages the species found in each county are briefly enumerated without authorities.

Adams County

Reboulia hemisphaerica, Conocephalum conicum, Marchantia polymorpha, Preissia quadrata, Metzgeria conjugata, Pellia epiphylla, Fossombronia foveolata, Chiloscyphus rivularis, Geocalyx graveolens, Harpanthus scutatus, Jungermannia pumila, Lophocolea heterophylla, Lophozia incisa, Nardia hyalina, Plagiochila asplenioides, Sphenolobus exsectus, Calypogeia trichomanis, Cephalozia catenulata, C. curvifolia, Trichocolea tomentella, Scapania nemorosa, Porella pinnata, Anthoceros laevis.

Ashland County

Conocephalum conicum, Preissia quadrata, Marchantia polymorpha, Riccardia latifrons, R. multifida, R. pinguis, Blasia pusilla, Fossombronia foveolata, Pellia epiphylla, Chiloscyphus pallescens, Geocalyx graveolens, Jamesoniella autumnalis, Jungermannia cordifolia, J. pumila, J. sphaerocarpa, Lophocolea heterophylla, Lophozia alpestris, L. badensis, L. barbata, L. heterocolpa, L. incisa, L. kaurini, L.

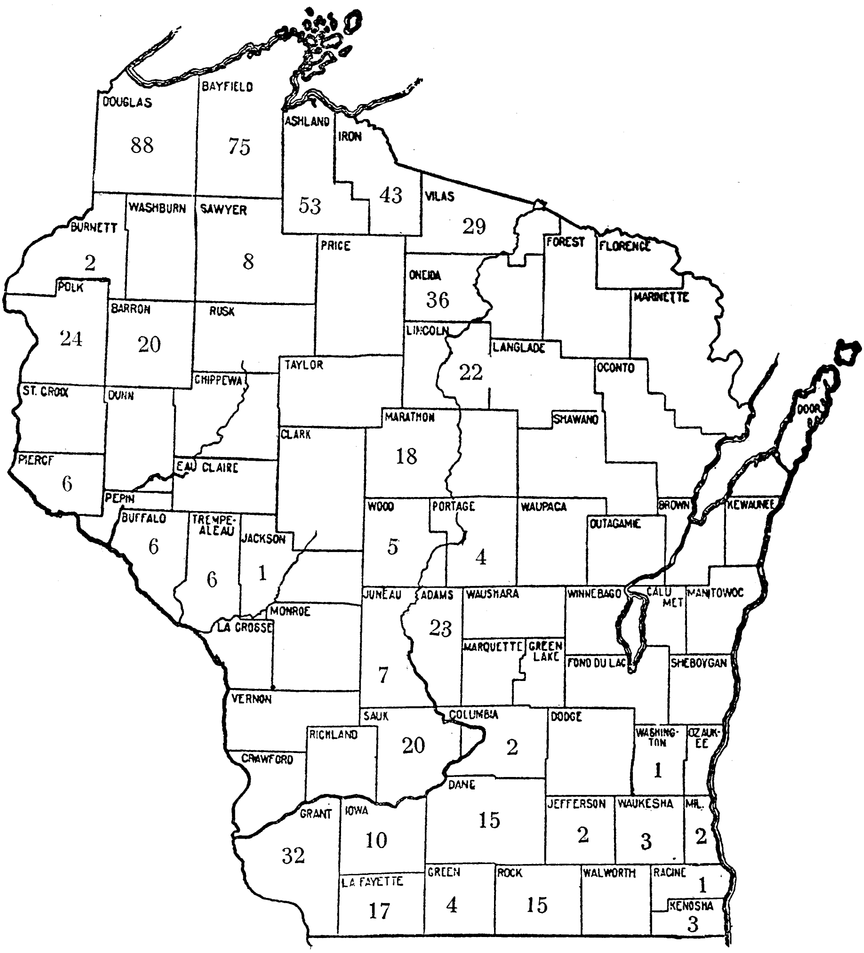

FIG. 1. County map of Wisconsin. Numerals designate the number of species which have been found in that particular county.

porphyroleuca, L. quinquedentata, L. ventricosa, Nardia hyalina, Plagiochila asplenioides, Sphenolobus exsectaeformis, S. exsectus, S. hellerianus, S. michauxii, Cephaloziella hampeana, Bazzania trilobata, Calypogeia trichomanis, Cephalozia bicuspidata, C. catenulata, C. curvifolia, C. media, Lepidozia reptans, Odontoschisma denudatum, Blepharostoma trichophyllum, Ptilidium pulcherrimum, Trichocolea tomentella, Scapania curta, S. irrigua, S. nemorosa, S. subalpina, Radula complanata, R. obconica, Porella platyphylla, P. platyphylloidea, Frullania asagrayana, F. eboracensis.

Barron County

Riccia fluitans, Pellia fabroniana, Geocalyx graveolens, Lophocolea heterophylla, Lophozia incisa, Plagiochila asplenioides, Bazzania trilobata, Calypogeia neesiana, Cephalozia media, C. pleniceps, Lepidozia reptans, Ptilidium pulcherrimum, Trichocolea tomentella, Radula obconica, Porella platyphylla, P. platyphylloidea, Frullania brittoniae, F. eboracensis, Blasia pusilla, Pellia epiphylla.

Bayfield County

Riccia fluitans, Ricciocarpus natans, Conocephalum conicum, Preissia quadrata, Marchantia polymorpha, Riccardia pinguis, R. latifrons, R. palmata, Pellia epiphylla, P. fabroniana, P. neesiana, Blasia pusilla, Fossombronia foveolata, Plagiochila asplenioides, Lophocolea heterophylla, L. minor, Chiloscyphus pallescens, Ch. fragilis, Ch. rivularis, Harpanthus scutatus, Geocalyx graveolens, Nardia hyalina, Jungermannia lanceolata, J. pumila, J. pumila var. rivularis, J. schiffneri, J. sphaerocarpa, Jamesoniella autumnalis, Lophozia alpestris, L. badensis, L. barbata, L. excisa, L. heterocolpa, L. incisa, L. kaurini, L. muelleri, L. quinquedentata, L. ventricosa, Sphenolobus exsectaeformis, S. exsectus, S. hellerianus, S. michauxii, Cephaloziella bifida, C. hampeana, C. myriantha, Cephalozia bicuspidata, C. curvifolia, C. pleniceps, Odontoschisma denudatum, O. macounii, Bazzania trilobata, Calypogeia neesiana, Blepharostoma trichophyllum, Ptilidium pulcherrimum, Lepidozia reptans, Diplophyllum apiculatum, Scapania apiculata, S. undulata, S. curta, S. cuspiduligera, S. dentata, S. glaucocephala, S. irrigua, S. nemorosa, S. paludicola, S. subalpina, Radula complanata, R. obconica, Proella platyphylla, P. platyphylloidea, Cololejeunea biddlecomiae, Frullania brittoniae, F. eboracensis, F. inflata, Anthoceros laevis.

BUFFALO COUNTY

Reboulia hemisphaerica, Lophocolea heterophylla, L. minor, Nardia hyalina, Anthoceros laevis, Geocaylx graveolens.

BURNETT COUNTY

Riccia arvensis, R. fluitans.

COLUMBIA COUNTY

Ricciocarpus natans, Porella platyphylloidea.

DANE COUNTY

Riccia arvensis, R. fluitans, Ricciocarpus natans, Grimaldia fragrans, Reboulia hemisphaerica, Conocephalum conium, Marchantia polymorpha, Pressia quadrata, Lophocolea heterophylla, Ptilidium pulcherrimum, Porella platyphylla, P. platyphylloidea, Frullania brittoniae, F. eboracensis, Nothothylas orbicularis.

DOUGLAS COUNTY

Riccia fluitans, Ricciocarpus natans, Rebouilia hemisphaerica, Conocephalum conicum, Marchantia polymorpha, Preissia quadrata, Pallavincinia flotowiana, Riccardia latifrons, R. multifida, R. palmata, R. pinguis, Blasia pusilla, Pellia epiphylla, P. fabroniana, P. neesiana, Chiloscyphus fragilis, Ch. pallescens, Ch. polyanthos, Ch. rivularis, Geocalyx graveolens, Harpanthus scutatus, Jamesoniella autumnalis, Jungermannia lanceolata, J. pumila, J. schiffneri, Lophocolea heterophylla, L. minor, Lophozia attenuata, L. badensis, L. barbata, L. bicrenata, L. guttulata, L. heterocolpa, L. incisa, L. kaurini, L. longiflora, L. muelleri, L. porphyroleuca, L. quinquedentata, Mylia anomala, Nardia hyalina, Plagiochila asplenioides, Sphenolobus exsectaeformis, S. exsectus, S. Hellerianus, S. michauxii, Cephaloziella bifida, C. byssacea, C. elachista, C. hampeana, C. myriantha, C. sullivantii, Bazzania trilobata, Calypogeia neesiana, C. trichomanis, Cephalozia bicuspidata, C. catenulaa, C. connivens, C. curvifolia, C. macounii, C. media, C. pleniceps, Lepidozia reptans, Odontoschisma denudatum, Blepharostoma trichophyllum, Ptilidium ciliare, Pt. pulcherrimum, Trichocolea tomentella, Diplophyllum gymnostomophilum, Scapania apiculata, S. curta, S. glaucocephala, S. irrigua, S. nemorosa, S. paludiocola, S. subalpina, Radula complanata, R. obconica, Porella platyphylla, P. platyphylloidea, Cololejeunea biddlecomiae, Frullania asaprayana, F. brittoniae, F. bolanderi, F. eboracensis, F. oakesiana, F. selwyiana, Anthoceros laevis.

Grant County

Riccia beyrichiana, R. sorocarpa, Grimaldia fragrans, G. pilosa, G. rupestris, Reboulia hemisphaerica, Conocephalum conicum, Marchantia polymorpha, Preissia quadrata, Chiloscyphus pallescens, Harpanthus scutatus, Jamesoniella autumnalis, Lophocolea heterophylla, L. minor, Lophozia incisia, Nardia hyalina, Plagiochila asplenioides, Sphenolobus exsectus, Cephaloziella bifida, Calypogeia neesiana, Lepidozia reptans, Ptilidium pulcherrimum, Scapania curta, S. nemorosa, Porella platyphylla, Frullania asagrayana, F. brittoniae, F. eboracensis, F. inflata, F. riparia, Anthoceros laveis, Frullania inflata.

Green County

Conocephalum conicum, Preissia quadrata, Lophocolea heterophylla, Porella platyphylloidea.

Iron County

Conocephalum conicum, Marchantia polymorpha, Preissia quadrata, Blasia pusilla Pellia epiphylla, P. neesiana, Chiloscyphus pallescens, Geocalyx graveolens, Harpanthus scutatus, Jamesoniella autumnalis, Jungermannia lanceolata, J. pumila, J. rivularis, J. schiffneri, Lophocolea heterophylla, L. minor, Lophozia badensis, L. barbata, L. heterocolpa, L. incisa, L. kaurini, L. quinquedentata, Nardia hyalina, Plagiochila asplenioides, Sphenolobus scitulus, Cephaloziella hampeana, Cephalozia curvifolia, C. pleniceps, Lepidozia reptans, Odontoschisma macounii, Blepharostoma trichophyllum, Trichocolea tomentella, Diplophyllum gymnostomophilum, Scapania curta, S. glaucocephala, S. subalpina, Radula complanata, Porella platyphylloidea, Cololejeunea biddlecomiae, Lejeuna cavifolia, Frullania asagrayana, F. eboracensis, Anthoceros laevis.

Iowa County

Riccia arvensis, R. fluitans, Marchantia polymorpha, Fossombronia (sterile), Lophocolea heterophylla, Nardia crenulata, Porella platyphylla, P. platyphylloidea, Frullania eboracensis, Anthoceros punctatus.

Jackson County

Chiloscyphus rivularis.

Jefferson County

Lophocolea heterophylla, Ptilidium pulcherrimum.

Juneau County

Reboulia hemisphaerica, Marchantia polymorpha, Preissia quadrata, Pellia epiphylla, Jungermannia pumila, Nardia hyalina, Anthoceros laevis.

Lafayette County

Marchantia polymorpha, Chiloscyphus fragilis, Harpanthus scutatus, Jamesoniella autumnalis, Jungermannia lanceolata, Lophocolea heterophylla, L. minor, Nardia hyalina, Sphenolobus exsectus, Cephaloia bicuspidata, Lepidozia reptans, Blepharostoma trichophyllum, Ptilidium pulcherrimum, Porella platyphylla, Frullania asagrayana, F. eboracensis, Anthoceros laevis.

Lincoln County

Conocephalum conicum, Riccardia palmata, Chiloscyphus fragilis, Ch. rivularis, Harpanthus scutatus, Jungermannia lanceolata, Lophocolea heterophylla, L. minor, Lophozia barbata, Bazzania trilobata, Cephalozia curvifolia, C. media, Lepidozia reptans, Ptilidium ciliare, Pt. pulcherrimum, Radula complanata, Frullania asagrayana, F. eboracensis, F. brittoniae, Lejeuna cavifolia, Anthoceros laevis, A. macounii.

Marathon County

Marchantia polymorpha, Pellia fabroniana, Chiloscyphus rivularis, Jamesoniella autumnalis, Lophocolea heterophylla, L. minor, Lophozia alpestris, Sphenolobus hellerianus, Bazzania trilobata, Cephalozia bicuspidata, C. catenulata, C. curvifolia, C. media, Ptilidium pulcherrimum, Scapania nemorosa, Radula obconica, Porella pinnata, frullania asagrayana.

Milwaukee County

Lophocolea heterophylla, Ptilidium ciliare.

Oneida County

Riccia fluitans, Conocephalum conicum, Marchantia polymorpha, Riccardia multifida, R. palmata, Blasia pusilla, Pellia neesiana, Chiloscyphus fragilis, Ch. pallescens, Ch. rivularis, Geocalyx graveolens, Jamesoniella autumnalis, Lophocolea heterophylla, Lophozia barbata, L. incisa, L. porphyroleuca, Plagiochila asplenioides, Sphenolobus hellerianus, Bazzania trilobata, Calypogeia neesiana, Cephalozia catenulata, C. connivens, C. curvifolia, C. macounii, C. media, C. pleniceps, Lepidozia reptans, Odontoschisma denudatum, Blepharostoma trichophyllum, Ptilidium pulcherrimum, Trichocolea tomentella, Radula complanata, Porella pinnata, P. platyphylloidea, Frullania asagrayana, F. eboracensis.

Pierce County

Conocephalum conicum, Preissia quadrata, Blasia pusilla, Chiloscyphus pallescens, Lophocolea heterophylla, Anthoceros laevis.

Polk County

Ricciocarpus natans, Asterella tenella, Grimaldia fragrans, Conocephalum conicum, Marchantia polymorpha, Preissia quadrata, Blasia pusilla, Pellia epiphylla, P. neesiana, Chilscyphus pallescens, Harpanthus scutatus, Jamesoniella autumnalis, Lophocolea heterophylla, L. minor, Lophozia barbata, L. quinquedentata, Ptilidium pulcherrimum, Radula complanata, Porella pinnata, P. platyphylla, P. platyphylloidea, frullania eboracensis, F. riparia, Anthoceros laevis, Grimaldia pilosa.

Portage County

Riccia fluitans, Pellia fabroniana, Lophocolea minor, Frullania inflata.

Racine County

Reboulia hemisphaerica.

Riccia arvensis, Grimaldia fragrans, Conocephalum conicum, Preissia quadrata, Marchantia polymorpha, Reboulea hemisphaerica, Lophocolea heterophylla, L. minor, Jamesoniella autumnalis, Ptilidium pulcherrimum, Porella platphylla, P. plalyphylloidea, Frullania brittoniae, F. eboracensis, F. reparia.

Sauk County

Riccia fluitans, Reboulia hemisphaerica, Marchantia polymorpha, Metzgeria conjugata, Pellia epiphylla, P. neesiana, Jamesoniella autumnalis, Lophocolea heterophylla, L. minor, Lophozia barbata, L. ventricosa, Plagiochila asplenioides, Nardia hyalina, Sphenolobus exsectus, Cephalozia curvifolia, Scapania nemorosa, Radula complanata, Porella platyphylla, Frullania eboracensis, Anthoceros laevis.

Sawyer County

Marchantia polymorpha, Riccardia latifrons, Jamesoniella autumnalis, Harpanthus scutatus, Lophocolea heterophylla, Bazzania trilobata, Cephalozia curvifolia, Porella platyphylla.

TREMPEALEAU COUNTY

Reboulia hemisphaerica, Nardia hyalina Porella platyphylla, Frullania eboracensis, Anthoceros laevis, Jungermannia pumila.

VILAS COUNTY

Conocephalum conicum, Marchantia polymorpha, Riccardia latifrons, R. pinguis, Pellia epiphylla, P. neesiana, Geocalyx graveolens, Jamesoniella autumnalis, Lophocolea heterophylla, Lophozia barbata, L. incisa, L. porphyroleuca, Plagiochila aspleniodes, Splenolobus exsectaeformis, S. hellerianus, S. michauxii, Bazzania trilobata, Cephalozia connivens, C. curvifolia, C. macounii, C. media, Lepidozia reptans, Odonto schisma denudatum, Blepharostoma trichophyllum, Ptilidium ciliare, Pt. pulcherrimum, Scapania paludicola, Porella platyphylla, Frullania eboracensis.

WASHINGTON COUNTY

Marchantia polymorpha.

WAUKESHA COUNTY

Riccia fluitans, Ricciocarpus natans, Lophozia heterocolpa.

WOOD COUNTY

Rebouila hemisphaerica, Conocephalum conicum, Pellia epiphylla, Harpanthus scutatus, Nardia hyalina.

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1. Cheney, L. S., and True, R. H. On the flora of Madison and vicinity, a preliminary paper on the flora of Dane County, Wisconsin. Trans. Wis. Acad. Sci., Arts & Let. 9 (1): 45–135. 1893. (Hepaticae, pp. 133, 134.)
2. Cheney, L. S. A contribution to the flora of the Lake Superior region. Trans. Wis. Acad. Sci., Arts & Let. 9 (1): 233–234. 1893. (Hepaticae, pp. 233, 254.)

3. —— Hepaticae of the Wisconsin Valley. Trans. Wis. Acad. Sci., Arts, & Let. 10: 70–72. 1895.
4. Allen, C. E. Some Hepaticae of the Apostle Islands. Trans. Wis., Acad. Sci., Arts & Let. 14 (2): 485, 486. 1904.
5. Conklin, G. H. Brief notes on the distribution of Hepaticae. Bryologist 15: 11, 12. 1912.
6. —— Preliminary report on a collection of Hepaticae from the Duluth-Superior district. States of Minnesota and Wisconsin. Trans. Wis. Acad. Sci., Arts & Let. 17 (2): 985–1010. 1914.

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. I. JUNCAGINACEAE, ALISMACEAE

NORMAN C. FASSETT

It is intended to issue from time to time, under this title, accounts of the ranges, so far as they are known, of certain groups of plants in Wisconsin. These reports are directed largely to amateurs, without whose help the study of the flora of any region is a tedious process. The professional botanist may visit any given locality, and perhaps find a fair proportion of the plants in flower or fruit at the particular time, but only the local botanist, watching the same region throughout the year and from year to year, can have a true conception of the local flora. By presenting graphically the known range of each plant it is hoped to show the amateur how he can help fill the gaps in our knowledge of these species. Plants familiar to him may prove to be important extensions of range.

These maps are compiled entirely from herbarium specimens in the herbaria of the University of Wisconsin, of the Milwaukee Public Museum and of Mr. S. C. Wadmond, Delavan, Wis. An important herbarium of Wisconsin plants, that of the late J. H. Schuette, is unfortunately not easily available. A number of Schuette's collections, however, are included in the herbarium of the late Professor L. M. Umbach, recently acquired by the University of Wisconsin. Specimens collected as hosts of fungi, particularly by Dr. J. J. Davis, have been used in making these maps only when their identity was absolutely certain.

JUNCAGINACEAE—ARROW GRASS FAMILY

1. SCHEUCHZERIA

S. PALUSTRIS L., var. AMERICANA Fernald, Rhodora 25: 178. 1923. (Fig. 1). The American phase of *Scheuchzeria* has been shown to differ from the European in the size and shape of the fruit. This plant occurs in *Sphagnum* bogs of northern and eastern Wisconsin. An unnamed locality in Oconto County is not shown on the map.

2. TRIGLOCHIN

T. MARITIMA L. (Fig. 2). Shore of Lake Superior, and occasional on small lakes in the interior. Is this really absent from the Lake Michigan shore? The station in Racine County is on Racine Prairie,[1] five miles from the lake.

T. PALUSTRIS L. (Fig. 3). Shore of Lake Michigan, in Door, Racine, and Kenosha Counties.

ALISMACEAE—WATER-PLANTAIN FAMILY

1. SAGITTARIA

S. LATIFOLIA Willd. (Fig. 4). The typical form of this species seems to be found throughout Wisconsin. Specimens from Tripoli, Oneida County (August 17 & 19, 1925, J. J. Davis) have the middle flowers perfect.

S. LATIFOLIA, f. HASTATA (Pursh) Robinson. (Fig. 5). Apparently absent from the lower Wisconsin and Mississippi Rivers.

S. LATIFOLIA, f. GRACILIS (Pursh) Robinson. (Fig. 6). Like the preceding, this form appears to be absent from southwestern Wisconsin.

S. LATIFOLIA, var. OBTUSA (Muhl.) Wiegand, Rhodora **27**: 186. 1925. *S. latifolia,* f. *obtusa* Robinson. (Fig. 7). Professor Wiegand's statement that "the obtuse leaf apex and the generally dioecious flowers as well as the rather definite range suggest a more racial difference" applies well to this plant as it grows in Wisconsin. It is the most conspicuous *Sagittaria* on the Mississippi River bottoms (in spite of the meagre collections from that region) forming large patches, each often made up entirely of plants of one sex.

S. CUNEATA Sheldon, Bull. Torr. Bot. Club **20**: 283. 1893. *S. arifolia* Nutt. in herb.; J. G. Smith, Rep. Mo. Bot. Gard. **6**: 32. 1895, and reprint, 6. 1894. (Fig. 8).

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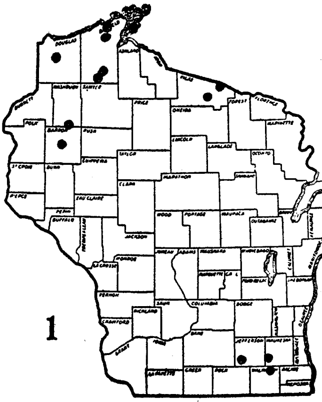
[1] Wadmond, Trans. Wis. Acad. Sci., Arts & Let. **16**:806. 1909.



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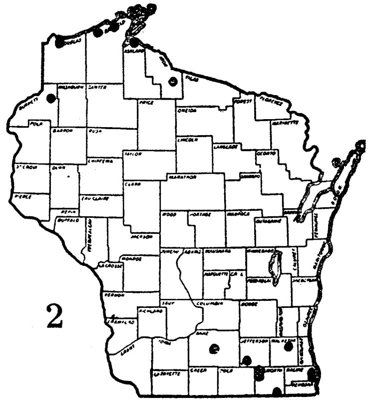

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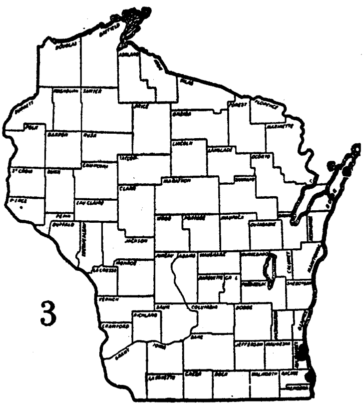

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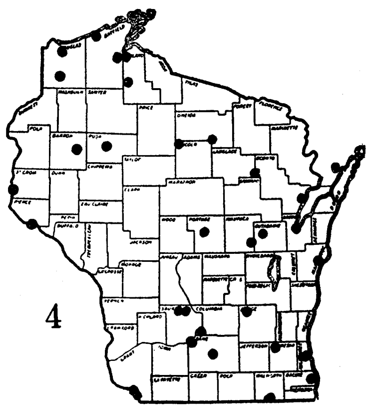

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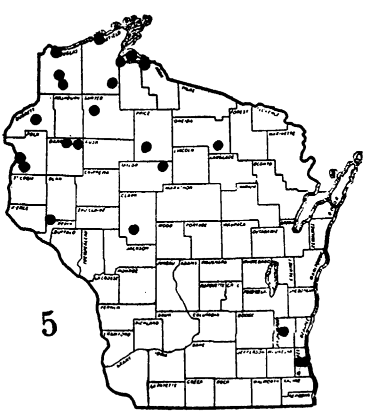

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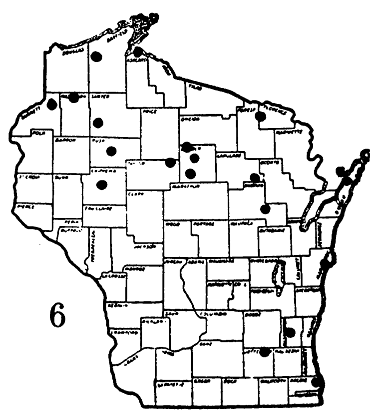

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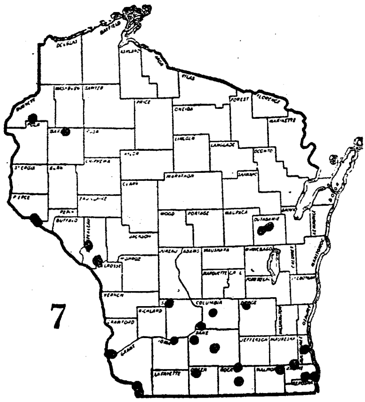

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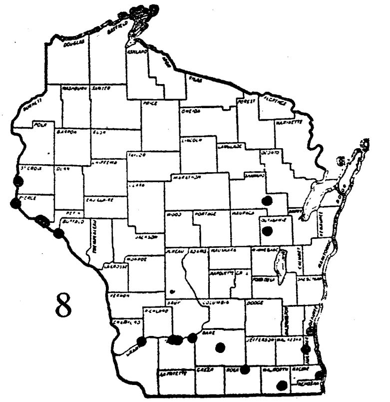

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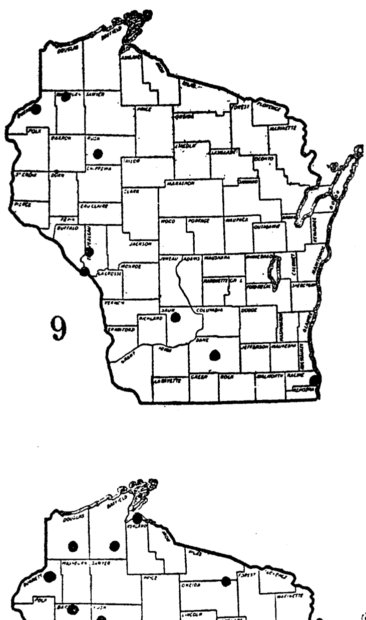

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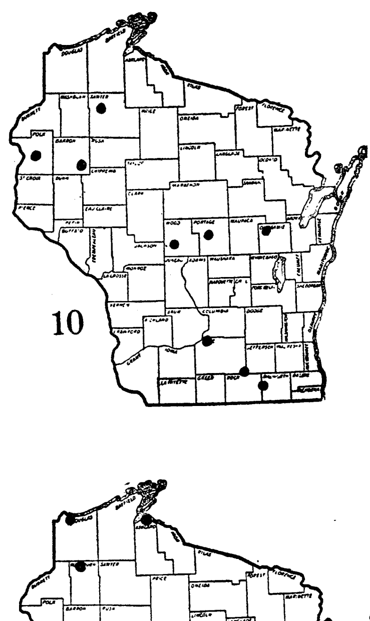

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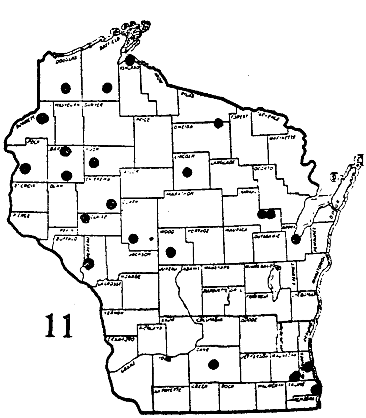

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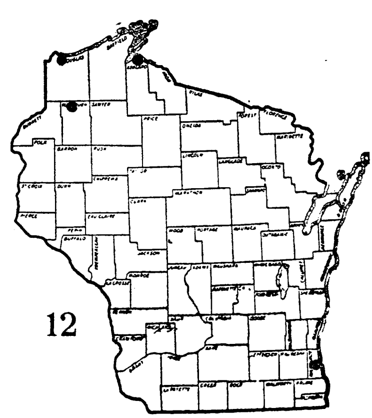

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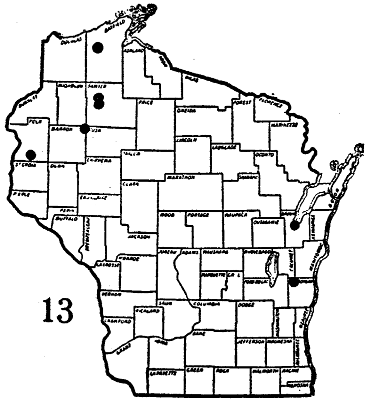

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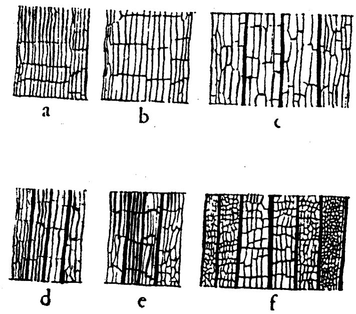

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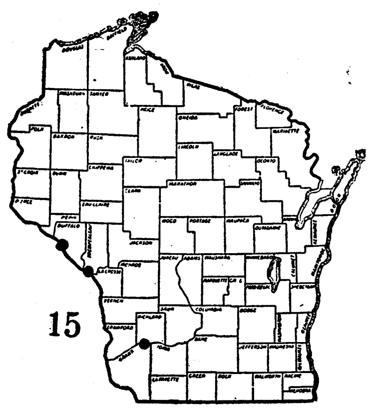

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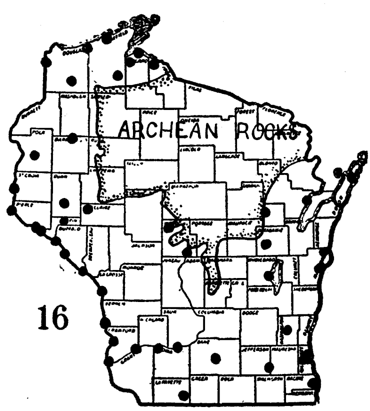

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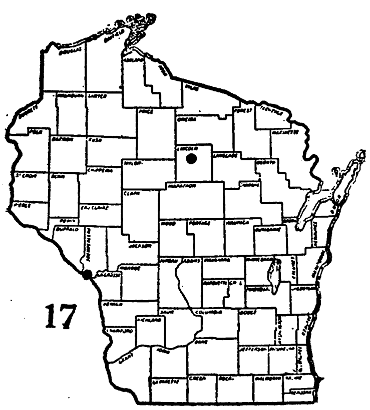

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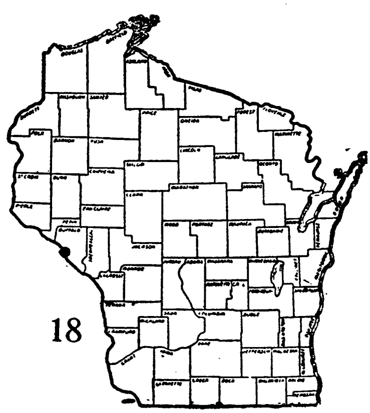

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Sands of the Mississippi and Wisconsin Rivers, and southern Wisconsin northward to Shawano County.

S. HETEROPHYLLA Pursh. Throughout the state, varying as to leaf-outline. The typical form (fig. 9) seems to be more common westward in the state, but is hardly distinguishable from f. *elliptica.*

S. HETEROPHYLLA, f. ELLIPTICA (Engelm.) Blake, Rhodora 15: 159. 1913. *S. heterophylla* Engelm. (Fig. 10). Scattered.

S. HETEROPHYLLA, f. RIGIDA (Pursh) Blake, l. c. *S. heterophylla,* var. *rigida* Engelm. and var. *angustifolia* Engelm. (Fig. 11). The commonest form.

S. HETEROPHYLLA, f. FLUITANS (Engelm.) Blake, l. c. (Fig. 12). This is a submerged form, with linear, usually almost bladeless leaves. Occurs rarely northward and eastward.

S. GRAMINEA Michx. (Fig. 13). Mostly northward.

This species and *S. cuneata* frequently form, when submerged, rosettes of narrowly lanceolate bladeless phyllodia. These forms, usually sterile, may be distinguished *in Wisconsin* as follows:

a. Phyllodia with 12–20 longitudinal veins of almost equal heaviness (fig. 14, a & b) ---------------------- *S. graminea*
a. Phyllodia with 3–5 heavy longitudinal veins, the interstices reticulate (fig. 14, e & f) --------------- *S. cuneata*

However, *S. graminea* is a complex species, and this character cannot be relied upon in other regions. It is a good distinction in material from Maine, but a large series of *S. graminea* from Illinois and Indiana (fig. 14, c & d) has the veination ascribed to *S. cuneata* in Wisconsin. Whether Michaux's type of *S. graminea* was the plant called by that name in Wisconsin or in Indiana, if either, must remain a question at present.

The *S. graminea* of New England is seldom, if ever, found with mature fruit. The plant of Wisconsin, apparently identical with it, at least in the veination of the phyllodia, occasionally sets fruit. A good series of this plant collected at Hayward by Professor E. M. Gilbert and the writer shows phyllodia and fruit. The achenes are like those ascribed by J. G. Smith[1] to *S. cristata* Engelm. It is

[1] Rep. Mo. Bot. Gard. 6: 53. 1895, and reprint, 27: 1894.

possible, then, that *S. cristata* is really the northern representative of the complex group passing as *S. graminea.* Michaux's type of *S. graminea* may be the same plant.

Figure 14 represents portions of the phyllodia of six collections, as follows: a, *S. graminea,* Bowdoinham, Maine, Fassett, no. 2847; b, *S. graminea,* Hayward, Wisconsin, Gilbert & Fassett, no. 7436; c, *S. graminea,* Clarke, Indiana, Umbach, June 4, 1898; d, *S. graminea,* Tolleston, Indiana, Umbach, July 7, 1900; e, *S. cuneata,* Troutdale, Maine, Fassett, no. 3626; f, *S. cuneata,* Bay City, Wisconsin, Fassett & Wilson, no. 5288.

2. LOPHOTOCARPUS

L. CALYCINUS (Engelm.) J. G. Smith. (Fig. 15). Rare, but probably sometimes passed by as a Sagittaria. Sandy shores of sloughs, etc., on the Mississippi and Wisconsin River bottoms. This is a range not uncommon for plants coming to Wisconsin from regions to the southward.

3. ALISMA

A. PLANTAGO-AQUATICA L. (Fig. 16). Dr. Gunnar Samuelsson of Stockholm, Sweden, has identified the Wisconsin *Alisma* of the University Herbarium. He separates our *A. Plantago-aquatica* as a variety distinct from the European plant.

The Wisconsin plant, as indicated by available specimens, is absent from the great north-central shield of Archean igneous rocks. Further field work must, however, check this apparent fact.

A. SUBCORDATUM Raf. (Fig. 17). Rare in Wisconsin. This is a segregate from the preceding species.

A. GRAMINEUM Gmel. (Fig. 18). This is the *A. Geyeri* of Gray's Manual. It has been collected in this state only once, at Alma. It was noted by the writer in the summer of 1926, growing abundantly at several points on the Mississippi River bottoms at Teepeota Point, below Wabasha, Minnesota, and again directly across the river from Alma. It seems to prefer damp places on the sand which silts in between the wing dams. (The Mississippi River Commission chart of 30 years ago[2] shows the river at Alma as being nearly a mile and a half wide, with a boom to direct logs to the head of West Newton Chute, on the Minnesota side. At the low water of August, 1926, the river was less than a half mile wide at this point, and a series of wing dams extended from Island 39 to Island 40, which had been well toward the middle of the stream in 1897. A shallow slough behind the new sand island formed about these wing dams was only knee-deep. This part of the river was 4-8 feet deep in 1897. It was on this shore that *A. gramineum* grew. This ground was flooded after the rains of September, 1926, and the plant could not be found at the same point in 1927.) The writer in 1926 spent an entire afternoon searching for this plant on the Wisconsin side of the river, and finally collected only two individuals, a few miles below Alma.

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[2] October 7, 1897.

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. II. ERICACEAE

NORMAN C. FASSETT

1. GENERAL DISCUSSION

The ranges of many ericaceous plants in Wisconsin illustrate the control of plant distribution by geological and physiographic features.

Bog plants are almost entirely absent from the unglaciated area of the southwestern part of the state. The topography of this area is of the type known as maturity, with maximum slopes, almost perfect drainage, no natural bodies of standing water (except, in this case, in the river-bottoms) and (except as noted below) no bogs. The rest of the state, recently glaciated, with many pockets where bogs may form, shows such sphagnicolous plants as Cranberries (*Vaccinium macrocarpon,* fig. 30, *V. Oxycoccos,* var. *ovalifolium,* fig. 29), Creeping Snowberry (*Chiogenes hispidula,* fig. 22), Leather Leaf (*Chamaedaphne calyculata,* fig. 18, and Bog Rosemary (*Andromeda glaucophylla,* fig. 17). Parts of Jackson and Wood Counties, in the unglaciated area, are flat and sandy, and the underground drainage is so obstructed as to produce standing water; here we find *Vaccinium macrocarpon* and the *Chamaedaphne.* The former is represented by four collections, and the latter by but two; future collections should show these species to be more abundant in this part of the state.

Dry-soil types are rare in the unglaciated area, but for another reason, concerned with the nature of the rocks themselves. Trailing arbutus (*Epigaea repens,* fig. 19), Bearberry (*Arctostaphylos Uva-ursi,* fig. 21), and the Blueberries (*Vaccinium pennsylvanicum,* fig. 24, and *V. canadense,* fig. 26) avoid the limy rocks of southern Wisconsin. On the maps of these species the distribution of the St. Croixian Sandstone is indicated, and the plants may be seen to be plentiful on this type of rock. They are equally plentiful on the granites and sandstones which lie north of this formation, but south of this mass, where it is overlain by Lower Magnesian and Galena Black River Domolites, they are rare, except where patches of sandstone are not only exposed by erosion but leached by weathering. Such places may be seen on Picture Rock near Mt. Vernon (Dane County), where *Gaylussacia baccata* and *Vaccinium pennsylvanicum* grow, and on Pine Bluff (named for its isolated grove of *Pinus Strobus*) at Brodhead (Green County) where *Epigaea repens* and *Vaccinium canadense* are found. This type of plant also follows the shore of Lake Michigan. Since the underlying rock here is Niagara Dolomite, the relation of these plants to sandy beaches, fossil or otherwise, should be investigated.

Plants preferring woods are more general, but hardly common, south of the granite and sandstone regions. These include Princess Pine (*Chimaphila umbellata,* fig. 1), Wintergreen (*Gaultheria procumbens,* fig. 20), and Indian Pipe (*Monotropa uniflora,* fig. 13).

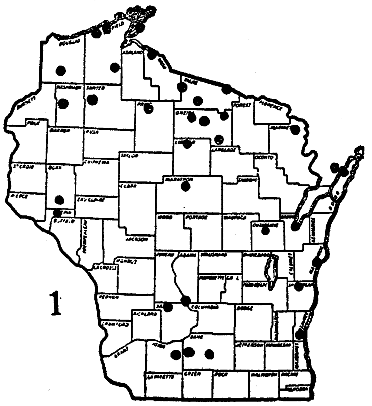
2. Ranges of Species and Varieties

The maps illustrating the following ranges are based on herbarium specimens seen by the writer. These specimens are in the Herbaria of the University of Wisconsin, of the Milwaukee Public Museum, and of Mr. S. C. Wadmond. Hosts of parasitic fungi in the Herbarium of the University of Wisconsin were also used to determine localities for these plants, except in the cases of *Pyrola* and *Vaccinium.*

CHIMAPHILA UMBELLATA (L.) Bart., var. CISATLANTICA Blake, Rhodora **19**: 241. 1917. *C. corymbosa* Pursh, in part; Rydberg, N. Am. Flora **29**, pt. 1: 31. 1914, in part. (Fig. 1). Common northward in Wisconsin, rather rare southward (see preceding paragraphs). The typical *Chimaphila umbellata* is a plant of Europe, not found in the United States.

MONESES UNIFLORA (L.) Gray. (Fig. 2). Common northward, very rare southward.

PYROLA MINOR L. (Fig. 3). Rare in Wisconsin, known only from Cornucopia, where it was collected by Mr. L. S. Cheney in 1897.



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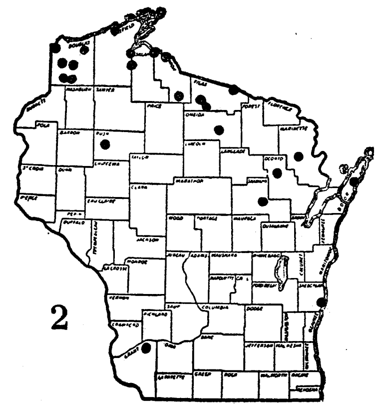

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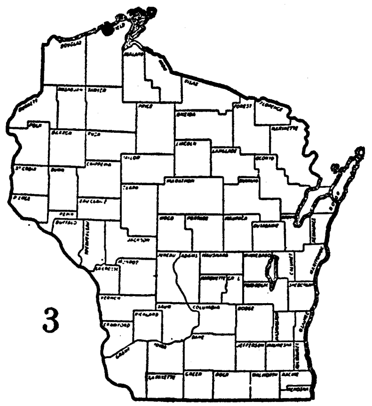

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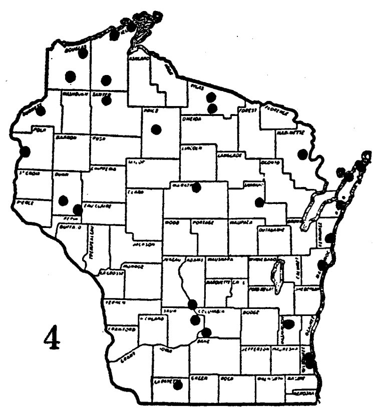

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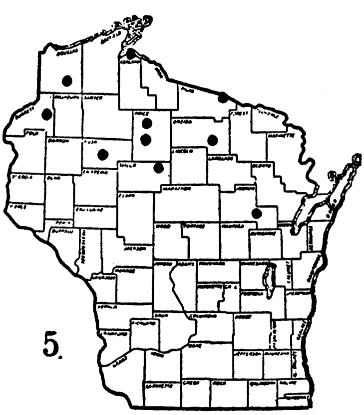

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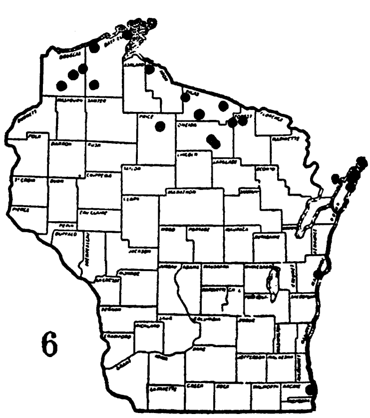

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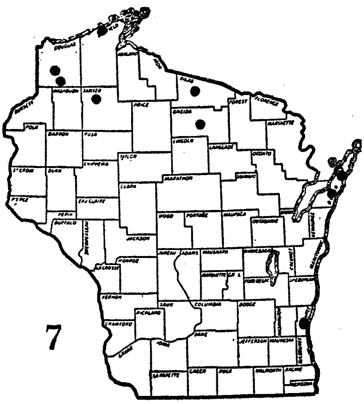

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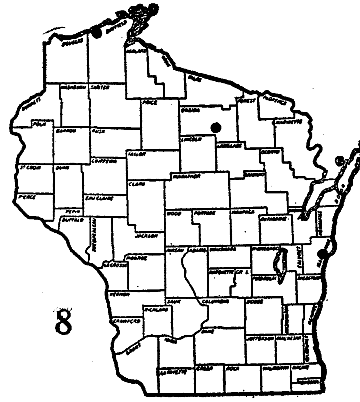

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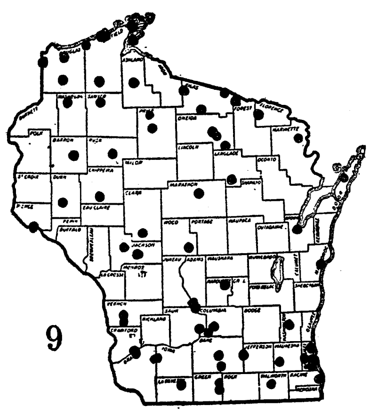

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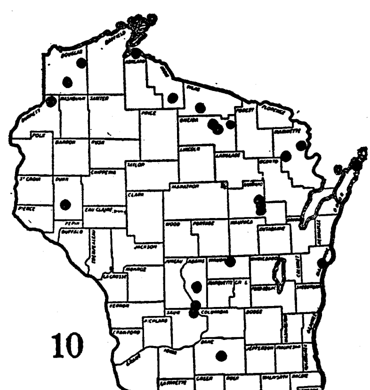

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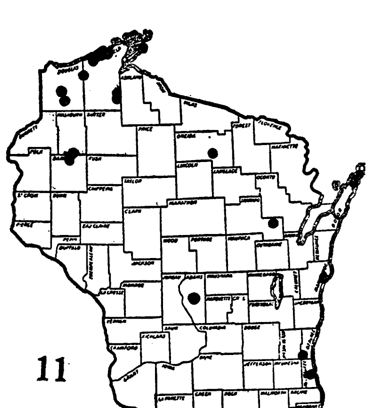

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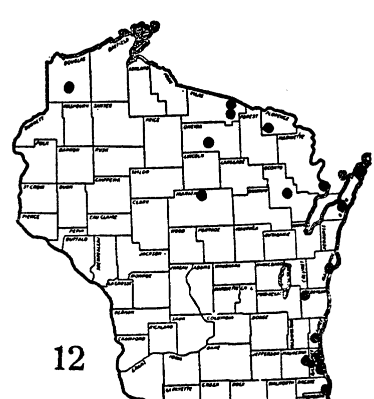

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P. SECUNDA L. (Fig. 4). Northern and eastern, with a few isolated stations in central southern Wisconsin.

P. SECUNDA, var. OBUSATA Turcz. (Fig. 5). Northward. The characters of this variety as given in the following key are mostly an abridgment of those listed by Fernald, *Rhodora* 28: 223, 1926.

P. CHLORANTHA Sw. (Fig. 6). Mostly northward, but south to Racine on the Lake Michigan shore.

P. CHLORANTHA, var. PAUCIFOLIA Fernald, Rhodora 22: 51, 1920. (Fig. 7). Range similar to the preceding.

P. CHLORANTHA, var. CONVOLUTA (Barton) Fernald, l. c., page 52. (Fig. 8). Less common. The portion of the key dealing with this species, on pages 262 & 264, is adapted from that of Fernald, l. c.

P. ELLIPTICA Nutt. (Fig. 9). Our most abundant representative of the family.

P. ROTUNDIFOLIA L., var. AMERICANA (Sweet) Fernald, Rhodora 22: 122, 1920. *P. americana* Sweet; Fernald, Rhodora 6: 201, 1904. (Fig. 10). Mostly northward.

In his earlier paper (1904) Fernald pointed out what he then considered specific characters to separate this plant from the European *P. rotundifolia,* but in 1920 he reported the discovery of a plant of Newfoundland (later found also in Novia Scotia) which showed intermediate characteristics. His description of this plant, var. *arenaria* Mert. & Koch, in 1920, reads much like that of his earlier description of typical *P. rotundifolia.* However, whatever may be the status of this intermediate, a comparison of the common American plant with that of Europe gives the impression that it is better treated as a variety than maintained as a species.

P. ASARIFOLIA Michx. (Fig. 11). Mostly northern, south rarely to Adams and Milwaukee Counties. (A station in southeastern Dunn Co. was inadvertently omitted from the map.)

P. ASARFOLIA, var. INCARNATA (Fisch.) Fernald. (Fig. 12). Perhaps more common eastward and southeastward than the preceding.

The following key to the species and varieties of *Pyrola* in Wisconsin is intended not to supplant, but to supplement, the treatments in the current manuals, and to point out some additional, mostly vegetative, characters.

a. Bracts, intermingled with the leaves at the base of the stem, crowded, usually 1 cm. or more long, obtuse, rounded or truncate at tip, often grading into leaves *b*

b. Cauline bracts 1–5 (very rarely none) ovate-lanceolate, their bases somewhat sheathing the stem; leaf-blades usually shorter than the petiole; sepals longer than broad *c*

c. Sepals ovate-lanceolate, rather blunt, twice as long as broad; petals white, rarely pinkish-tinged, 6.5–10.5 mm. long --- *P. rotundifolia*, var. *americana.*

c. Sepals triangular, acute or acuminate, rarely more than 1.5 times as long as broad; petals pink, about 5 mm. long *d*

d. Leaf-blades cordate at base ---------- *P. asarifolia.*

d. Leaf-blades subtruncate, rounded, or tapering at base ---------------- *P. asarifolia*, var. *incarnata.*

b. Cauline bracts none, or 1–3, narrowly lanceolate, long-acuminate, not sheathing; leaf-blades longer than the petiole; sepals about as broad as long *e*

e. Leaf-blades 3–7 cm. long, tapering at base; style declined; stigma not peltate --- *P. elliptica.*

e. Leaf-blades 2–4 cm. long, rounded or truncate at base; style straight; stigma peltate ------------------------ *P. minor.*

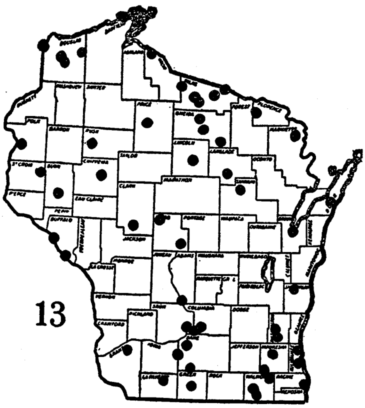
a. Basal bracts 2–4 mm. long, acute or acuminate, distinct from the leaves, often absent *f*

f. Leaf-margins crenate-serrate, usually with minute teeth; scape with (1–) 2–4 ovate-lanceolate bracts *g*

g. Basal bracts lanceolate, strongly involute, firm; leaf-blades narrowed at tip, 1.5–6 cm. long ------------------ *P. secunda.*

g. Basal bracts oblong to ovate, slightly involute, membranaceous; leaf-blades rounded at tip, 0.8–3 cm. long ------ *P. secunda*, var. *obtusata.*

f. Leaf-margins entire or somewhat undulate; scape naked or rarely with 1 or 2 short setaceous bracts *h*



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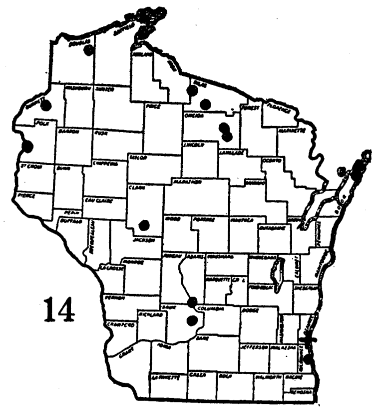

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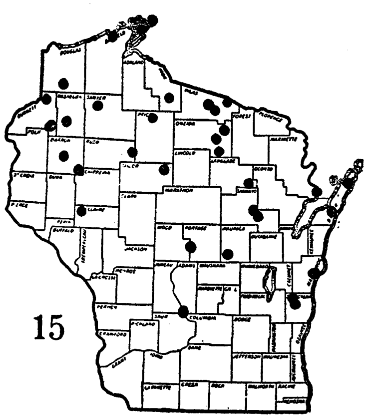

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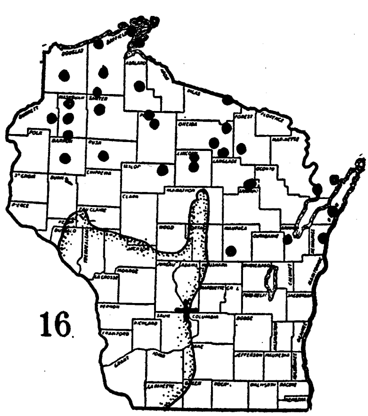

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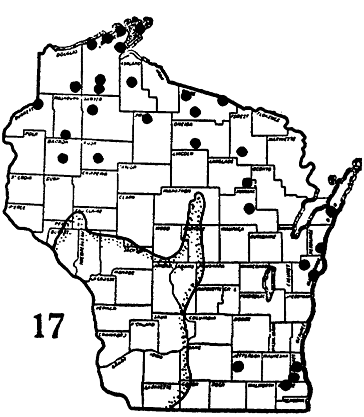

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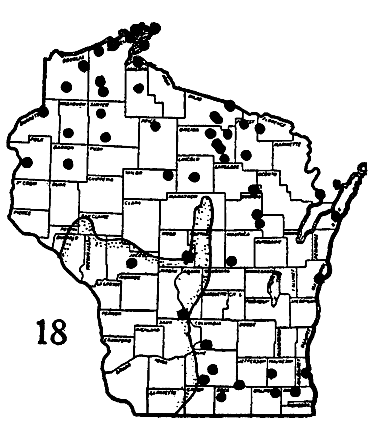

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h. Leaf-blades 0.7–3.3 cm. broad; calyx 3–4 (–5) mm. broad; anthers 1.6–3 (–3.3) mm. long *i*

i. Leaf-blades rounded to base and apex, 1.5–3.3 cm. broad, 4–11 in a rosette *P. chlorantha.*

i. Leaf-blades mostly cuneate at base and truncate or subtruncate at summit, 0.7–2.5 cm. broad, 0–7 in a rosette *P. chlorantha,* var. *paucifolia.*

h. Leaf-blades 2–4.5 cm. broad; calyx 4.8–6 mm. broad; anthers 3–4 mm. long__ *P. chlorantha,* var. *convoluta.*

MONTROPA UNIFLORA L. (Fig. 13). Throughout the state, but rare in the unglaciated region, probably because of the scarcity of damp woods there. Indian Pipes are sometimes found, in this state, in deep *Sphagnum.*

M. HYPOPITYS L. (Fig. 14, dots). In woods, generally distributed, but not common.

PTEROSPORA ANDROMEDEA Nutt. (Fig. 14, cross). Collected but once in Wisconsin, by Mr. Alvin Throne, at Donges Bay, Ozaukee County, August 15, 1928.

LEDUM GROENLANDICUM Oeder. (Fig. 15). Mostly northward. Comes south to the Dells of the Wisconsin River, where it grows on dry sandstone ledges along the river.

RHODODENDRON LAPPONICUM (L.) Wahlenb. (Fig. 16, cross). This plant was collected but once in Wisconsin, on May 30, 1898, by Mr. L. S. Cheney, on the high sandstone walls of the gorge cut by the Wisconsin River at Kilbourn, in the Dells. It has not been seen there since 1898.

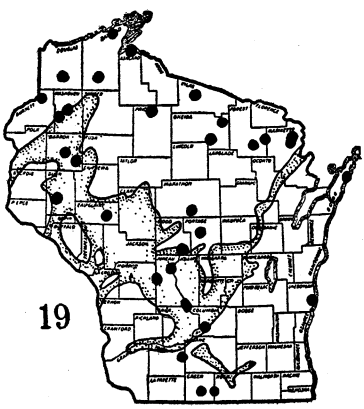
KALMIA POLIFOLIA Wang. (Fig. 16, dots). Mostly northern, in *Spahgnum* bogs.

ANDROMEDA GLAUCOPHYLLA Link. (Fig. 17). The unglaciated area is indicated on the map; see page 257.

CHAMAEDAPHNE CALYCULATA (L.) Moench. (Fig. 18). The unglaciated area is indicated on the map; see page 257.

EPIGAEA REPENS L. (Fig. 19). The area of St. Croixian Sandstone is indicated on the map; see page 257.

GAULTHERIA PROCUMBENS L. (Fig. 20). Rare southward. The most abundant colonies I have seen in the southern part of the state are in the pine woods at the Dells of the Wisconsin River, in Adams County.



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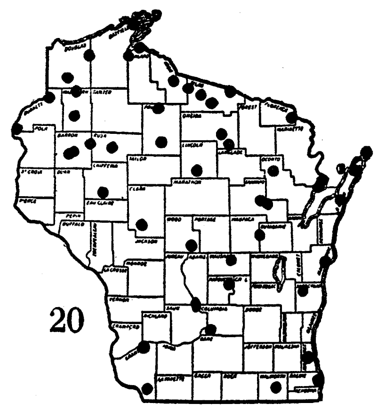

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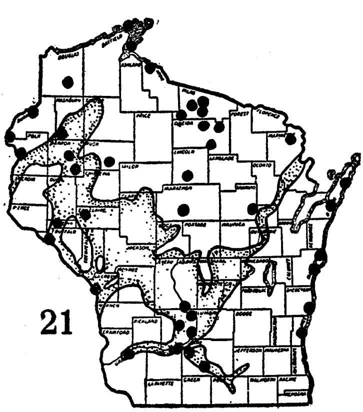

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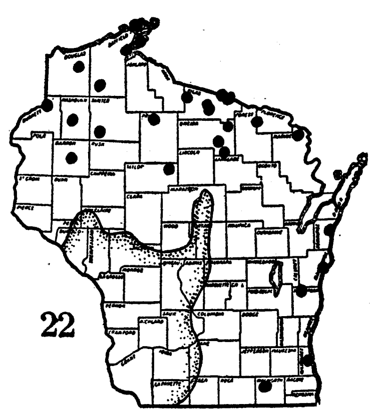

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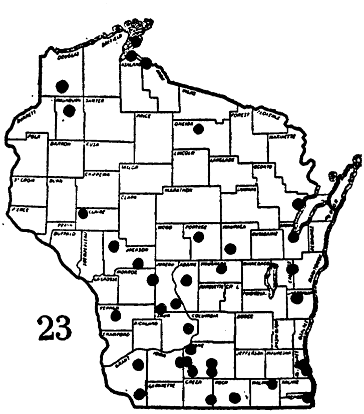

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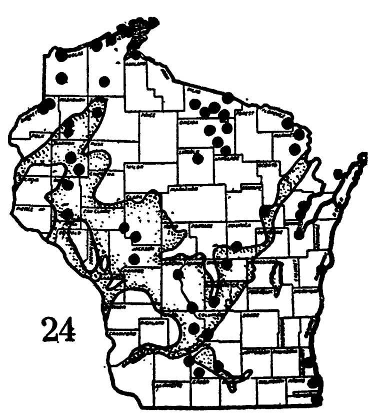

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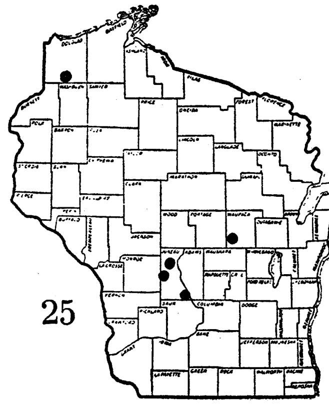

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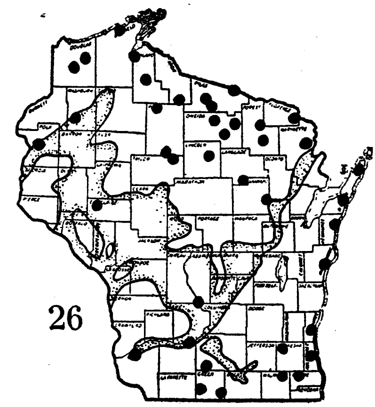

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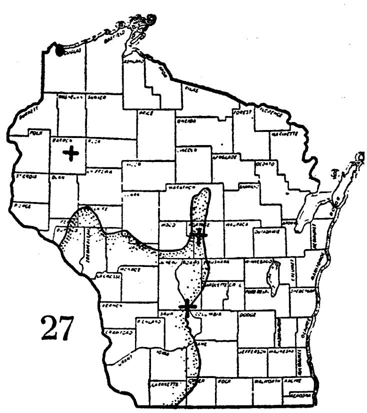

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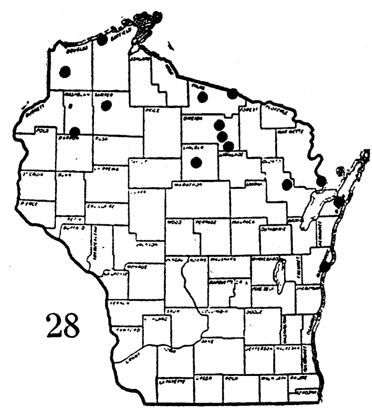

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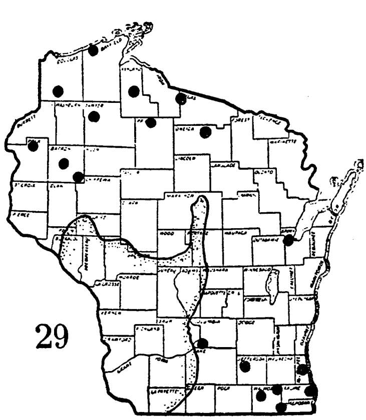

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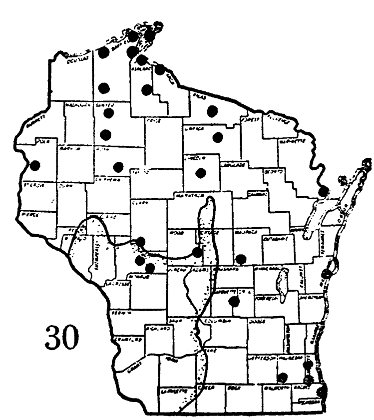

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ARCTOSTAPHYLOS UVA-URSI (L.) Spreng., var. COACTILIS Fernald & Macbride, Rhodora **16**: 212, 1914. (Fig. 21). The area of St. Croixian Sandstone is indicated on the map; see page 257. The Bearberry of this region differs slightly from the typical form of the European plant in the character of the tomentum of the twigs, and has been varietally separated on that character.

CHIOGENES HISPIDULA (L.) T. & G. (Fig. 22). The unglaciated area is indicated on the map; see page 257.

GAYLUSSACIA BACCATA (Wang.) K. Koch. (Fig. 23). Although apparently more abundant southward, this species is, south of the sandstone area, largely confined to the sandstone outcrops discussed in connection with *Epigaea repens*, etc., on pages 257–258.

VACCINIUM PENNSYLVANICUM Lam. (Fig. 24). The area of St. Croixian Sandstone is indicated on the map; see page 257.

V. PENNSYLVANICUM, var. MYRTILLOIDES (Michx.) Fernald, Rhodora **10**: 148, 1908. This northern pubescent extreme was collected by the writer in dry woods on the Elephants Back, near the Dells of the Wisconsin River, Adams County, on May 19, 1929.

V. PENNSYLVANICUM, var. NIGRUM Wood. (Fig. 25). Most of our collections of this variety are from central Wisconsin, but it is probably more widespread than these would indicate. Dr. J. J. Davis tell me that he has seen it in Door County.

V. CANADENSE Kalm. (Fig. 26). The area of St. Croixian sandstone is indicated on the map; see page 257.

V. CESPITOSUM Michx. Fig. 27, crosses). The unglaciated area is indicated on the map. This is one of the species accredited with preglacial age by Fernald, Mem. Am. Acad. Sci. **15**: 282, 1925. Of the three known stations in Wisconsin two are in the unglaciated area and one is to the north of it. This is in line with the ranges of a number of plants which seem to have survived the glacial period in this region, and to have worked northward since the recession of the ice, as, for example, *Epipactis decipiens* on the south shore of Lake Superior, and *Orplopanax horridum* on Isle Royale. Indeed, *Vaccinium cespitosum* is also found north of Wisconsin, on the Upper Peninsula of Michigan and the north shore of Lake Superior.

V. VITIS-IDAEA L., var. MINUS Lodd. (Fig. 27, dot). This plant has long been known from Grand Marais, Minnesota, near Duluth, and in 1926 it was collected in Superior, Wisconsin, by Mr. L. R. Wilson, of that city.

V. OXYCOCCOS L. (Fig. 28). Northern.

V. OXYCOCCOS, var. OVALIFOLIUM Michx.; Robinson & Fernald, Rhodora 19: 54, 1909. Var. *intermedium* Gray. (Fig. 29). The unglaciated area is indicated on the map; see page 257.

V. MACROCARPON Ait. (Fig. 30). The unglaciated area is indicated on the map; see page 257. Cranberries are one of the important crops of Wisconsin, the yield being surpassed only by those of Massachusetts and New Jersey. An old collection by T. J. Hale is marked "St. Croix"; this may be St. Croix Falls (where the plant has since been collected), or Upper Lake St. Croix (Douglas County), or somewhere along the St. Croix River between these points.

NOTES ON PARASITIC FUNGI IN WISCONSIN. XV

J. J. DAVIS

In "Notes" XIV, p. 185, *Taphrina struthiopteridis* Nishida was recorded as occurring in Wisconsin. On referring to the specimen in the herbarium it is found to be labeled *Taphrina hiratsukae* Nishida.

In *Annales Mycologici* 23: 63–4 is a note by Petrak on *Phyllosticta iridis* Ell. & Mart. in which he refers it to Phlyctaena. As he stated, the material that he examined was over-mature. Had he examined younger material he would have found that the pycnidia are perfect and hence that there is no need of removing it from Phyllosticta because of imperfect pycnidia.

Ascochyta wisconsina Davis ("Notes" II, 101) was referred to that genus because a few septate sporules were found. In a recent collection on *Sambucus canadensis* nearly all of the sporules have a median septum. Some of them are a little longer (12μ) than the description indicated.

In the original description of *Septoria pachyspora* Ell. & Hol. the pycnidia are said to be "on snow-white, thin, small (1–2 mm.), subangular to nearly round spots surrounded by a broad purplish shaded border" *(Journ. Mycol.* 1: 6). In the record of its occurrence in Wisconsin it was stated that the spots lacked the colored border *(Trans. Wis. Acad.* 9: 177). In a recent collection (Brodhead, Wis., Sept. 26, 1926) the leaves are somewhat faded and yellowish and the spots are merely small areas that have retained the deep green color with a tendency to become blackish in the central portion, the location of the pycnidia being indicated by whitish points due to exuded sporules. In the original description, which was copied in Martin's "Septorias of North America" *(Journ. Mycol.* 3: 67) the width of the sporules was given as 3μ which was perhaps a misprint for 5μ inasmuch as they approach the phragmosporous form as indicated by the specific name that was applied. In some collections the spots become arid and the sporules are narrow, probably because of unfavorable conditions. In reporting upon the determination of specimens a well known mycologist, who has described many species of North American Fungi, stated that he had been influenced more by the character of the spots than by those of the spores. It has become evident that spot characters depend largely on environmental influences affecting the host and should be used with caution in taxonomy.

A specimen on leaves of Helianthus from Lynxville (July 17, 1916) shows angular spots 2-5 mm. in diameter which are black-brown above, lighter on the lower surface. The pycnidia are hypophyllous, small, scattered, the sporules mostly curved, 27–37 x 1–1½μ. This is labeled *Septoria paupera* Ellis. The host is a form with rather thin triple-nerved leaves.

By an unfortunate error it was stated in "Notes" XIII, p. 172, that *Fungi Columbiana* 2593 represents *Gloeosporium niveum* Davis. The number should be 3491, 2593 being as labeled.

What appears to be the parasite recorded in "Notes" I, p. 89 under the name *Colletotrichum helianthi* n. sp. was distributed in Ellis & Everhart *North American Fungi,* second series *2778* as *Vermicularia helianthi* n. sp. The specimen is from Kansas on *Helianthus rigidus* collected by W. T. Swingle. Apparently no description was published.

In "Notes" XI, p. 291, the statement was made that I had seen no description of the parasite on *Fraxinus oregana* issued in *Fungi Columbiani 4415, 4719,* and *4816* under the name *Cylindrosporium fraxini* (Ell. & Kell.) Ell. & Ev. Ellis & Everhart *North American Fungi,* second series *1634, Septogloeum fraxini* Hark. is the same fungus. As the material was provided by Dr. Harkness it may be assumed to be authentic, but the description of the spots as given in Saccardo, *Sylloge Fungorum* 3: 802, "Maculis minutis, albidis, angulosis" would not suggest it.

In the first "supplementary list of parasitic fungi of Wisconsin" *Phleospora oxyacanthae* (Kze. & Schm.) was recorded as occurring in the state. In carrying this over into the "provisional list" the specific name was erroneously printed "crataegi". In "Notes" III, p. 254, a short description of the parasite was given showing characters quite different from those of Phleospora. In "Notes" X it was stated that it had been compared with an authentic specimen of *Cercosporella mirabilis* Pk. with which it agreed. Since then I have examined *Cylindrosporium crataegi* Ell. & Ev. as represented in *North American Fungi* 3182 and find that to be the same parasite. I do not find the acervuli mentioned by Ellis & Everhart *(Proc. Acad. Nat. Sci. Phila. 1894*, p. 372) nor yet differentiated conidiophores as stated by Peck and am labeling it **Cercoseptoria crataegi** (E. & E.) n. comb. Peck stated that "This is a remarkable, aberrant and variable species and possibly the type of a new genus" (Report of the State Botanist, 1911, p. 46). The genus to which it is here referred had not at that time been proposed. Infected leaves may be unspotted or spotted in various degrees, apparently according to age and amount of infection.

Saccardo referred to *Cercospora nasturtii* Pass. as subspecies *barbareae,* a form on *Barbarea vulgaris,* and figured it in *Fungi Ital. del. 648.* A collection on *Barbarea stricta* from Wauwatosa, however, bears more cylindrical and multiseptate conidia like those of *Cercospora armoraciae* Sacc. as figured in *F. Ital. del. 646.* In this collection on *Barbarea stricta* both conidiophores and conidia range up to 125μ or more in length. It may be that such forms on Cruciferae as have been named *C. nasturtii* Pass., *C. armoraciae* Sacc., C. *cheiranthi* Sacc. etc., will be found to be conspecific. Examination of a specimen labeled *Cercospora cruciferarum* E. & E. in Ellis & Everhart, *North American Fungi, 1995,* showed *Septoria sisymbrii* Ellis.

In "Notes" VIII, p. 429, record was made of a Cercospora on *Lespedeza capitata* with the suggestion that it was perhaps a northern form of the parasite which Atkinson described, from material collected in Alabama, as *Cercospora flagellifera.* The Wisconsin plant is doubtless *Cer-*

cospora lespedezae Ell. & Dearn. which was described from Canadian material. Length of conidiophores and of conidia are variable characters in this genus. *Cercospora latens* Ell. & Ev. is probably a form of the same species. In the description of this (*Journ. Mycol.* 4: 3), the host was given as *Psoralea argophylla*, but the error was later corrected.

In "Notes" XIV the statement was made that *Amphicarpa monoica* had been infected in the greenhouse with teliospores from Andropogon as the infecting agent and *Aecidium falcatae* Arth. as the result. In the spring of 1926 infection of *Andropogon furcatus* was brought about in the greenhouse from exposure to aeciospores from Amphicarpa.

In June, 1926, *Aecidium xanthoxyli* Pk. was found in abundance on *Zanthoxylum americanum* in the bottomlands opposite Sauk City, but no clue had been secured as to the alternate host. However, having potted plants of *Andropogon furcatus* in the greenhouse they were exposed to infection from the Aecidium, with the result that uredinia and at length telia developed. The uredospores from this infection are of the *Puccinia pustulata* type referred to in *North American Flora* as the Santalaceous race. The situation with regard to Puccinia on Andropogon is evidently somewhat complicated. As the plants of Andropogon that were infected by aecia on Amphicarpa and on Zanthoxylum had the same origin there is no question of racial differentiation of the telial hosts.

The first collection of aecia of *Puccinia sorghi* Schw. in Wisconsin was made at Blue River, June 19, 1926 on *Oxalis corniculata*. The aecidium was abundant in a station but a few feet across on an old road running through brushland. A collection on *Oxalis "cymosa?"* was made on the University farm July 20, 1926, by J. G. Dickson.

A Phragmidium which occurs commonly in Wisconsin on *Potentilla canadensis* was recorded under the name *Phragmidium potentillae-canadensis* Diet. with the description of which all American specimens that I have examined agree. This was separated from *Ph. tormentillae* Fckl. (*Ph. obtusum* (Strauss) Lk.) of Europe because of the smaller number of cells in the teliospores. October 2, 1925 a collection on *P. canadensis* was made at Madison having teliospores extremely variable in size and septation from which the following notes were made: Teliospores straight or somewhat curved, 33–280μ long, 2–16 celled, the cells either uniform or varying in length and width in the same spore, the septa usually transverse but exceptionally more or less oblique. Size of individual cells measured 15–36$\times$14–33μ. Germ pores single. As but one collection of this character has been made it is presumably an abnormal development. Occasionally there is an appearance that suggests proliferation of spores, but usually it seems more like proliferation of cells.

Additional Hosts

Peronospora ficariae Tul. A very scanty development on radical leaves of *Ranunculus abortivus.* Blue River.

Erysiphe cichoracearum DC. occurred at Brodhead on *Artemisia ludoviciana.* Perithecia were very few but pycnidia of Cicinnobolus were abundant but sterile.

Pseudopeziza medicaginis (Lib.) Sacc. On *Melilotus alba.* Madison. (F. R. Jones) Sometimes abundant on this host.

Phyllosticta decidua Ell. & Kell. On *Eupatorium sessilifolium.* Prairie du Chien.

Septoria anemones Desm. On *Anemone virginiana.* Potosi. I have seen no record of the occurrence of the parasite on this host. The specimen corresponds with some of those on *A. nemorosa.*

In the provisional list *Aster Shortii* was recorded as a host of *Septoria solidaginicola* Pk. A recent collection on this host made at Lynxville, July 17, 1926, however, is of quite a different type as is indicated by the following notes. Spots suborbicular, purple to brown above, lighter brown below, often containing a small white arid spot, mostly 4–5 mm. in diameter; pycnidia few, scattered, globose to depressed-globose, extending through the leaf from epidermis to epidermis but the ostiole epiphyllous where the wall is thickest, 100–165μ in diameter; sporules usually somewhat curved, tapering toward the acute apex, 50–85×3μ. This is referred to *Septoria atropurpurea* Pk.

From a collection on *Aster sagittifolius* made at Madison September 29, 1925 the following notes were made: spots brown, suborbicular to angular, 5–10 mm. in diameter, sometimes confluent; conidiophores amphigenous, more abundant below, fasciculate from a more or less stromatoid base, hyaline, straight or somewhat curved, cylindrical to subulate-cylindrical, usually simple, continuous, 12–30 x 2–3½μ; conidia hyaline, cylindrical, mostly 1–3 septate, sometimes catenulate, 15–50×2–3μ. The longer conidia become uniformly 3-septate. This has been labeled *Ramularia virgaureae* Thuem. Perhaps it bears relation to *Cercospora viminei* Tehon.

Cercosporella pyrina Ell. & Ev. On *Pyrus ioensis*. Brodhead. In this collection the conidia are 25–50×6–8μ. What appear to be immature perithecia occur beneath the upper epidermis.

Cercospora caricina Ell. & Dearn. On *Carex folliculata*. Millston.

Cercospora umbrata Ell. & Hol. On *Bidens connata*. Bridgeport and Camp Douglas. On *Bidens vulgata*. Sheboygan Falls.

A collection on *Ambrosia psilostachya* (Brodhead, Sept. 13, 1926) bears Cercospora on spots which are amphigenous, immarginate, at first yellowish green, then yellow and finally brown with death of the included tissue, 2–5 mm. in diameter, often confluent; conidiophores sometimes fasciculate, sometimes erect racemose branches from superficial brown, repent hyphae or from scandent hypae that ascend the trichomes, sub-hyaline, straight or somewhat tortuous or geniculate, continuous, rarely branched, 20–40×4–6μ; conidia hyaline, obclavate-cylindrical, straight or somewhat curved, 50–100×4μ. The common Cercospora on *Ambrosia trifida* has been referred to *Cercospora racemosa* Ell. & Mart. *(Fungi Columbiani 2117)* and *Cercospora ferruginea* Fckl. *(F. Col. 3207)*. The former reference was based largely upon finding infected Teucrium and Ambrosia growing together but field observation in Wisconsin suggests that the propinquity was casual. The specimen has been labeled *Cercospora ferruginea* Fckl. It will probably be some time before the relationships of the brown Cercosporas on Compositae become known. In a growth of the kind referred to here there is room for argument as to where mycelium ends and condiophores begin. On *Ambrosia trifida* the conida are sometimes terete, constricted at the septa, moniliform or finally catenulate. Apparently it has never been found on the ubiquitous *Ambrosia artemisiaefolia.*

Uromyces plumbarius Pk. Uredinia on *Gaura biennis.* Brodhead.

Puccinia vilfae Arth. & Hol. Aecia (*Aecidium verbenicolum* Ell. & Kell.) on *Verbena urticaefolia* and *V. stricta.* Prairie du Chien. This was abundant especially on the latter host. The telial stage on *Sporobolus asper* was recorded in the provisional list as *Puccinia sydowiana* Diet., a binomial that had been earlier proposed by Zopf for another rust.

Puccinia muhlenbergiae Arth. & Hol. On *Muhlenbergia sylvatica.* Blue River.

ADDITIONAL SPECIES

Not previously reported as occurring in Wisconsin.

Peronospora phlogina Diet. & Hol. This was found in very small quantity, with oospores, on *Phlox divaricata* at Blue River.

Venturia gaultheriae Ell. & Ev. On *Gaultheria procumbens.* Camp Douglas.

Taphrina filicina Rostr. On *Cystopteris fragilis.* Brodhead.

A collection on leaves of *Acer saccharum* seedlings made at Sheboygan was taken in the field for *Gloeosporium saccharinum.* On examination, however, it proved to be a Septoria and one that does not agree with any species of which I have knowledge. The following notes were made: On large dead leaf areas 2–5 cm. across which are reddish brown, becoming pale with age; pycnidia epiphyllous, scattered, depressed-globose, 70–130μ in diameter, wall usually thick and black about the ostiole; sporules acicular, straight, long acuminate, continuous, 20–30 x 1–2μ. On leaves of seedling *Acer saccharum*. Sheboygan, Wisconsin, August 26, 1926. For the purpose of filing in the herbarium this has been provisionally referred to *Septoria seminalis* Sacc. as *forma orthospora*. I have seen no specimens of this species which is said to occur on cotyledons of *Acer campestris* and to have falcate sporules. The status of this parasite awaits further information.

Septoria dodecatheonis n. sp. Spots dark olivaceous, varying from circular or angular 2–4 mm. in diameter to elongate 1 cm. in length, often confluent and with the death of intervening and surrounding leaf tissue forming considerable areas; pycnidia small, numerous, scattered, globose to ovoid or even flask-shaped, wall black, compact, ostiole more or less prominent, 50–80μ in diameter; sporules hyaline, straight, 20–40 x 1–1½μ. On leaves of *Dodecatheon Meadia*. Blue River, Wisconsin, June 18, 1926. The material is not quite mature and the mature sporules are probably somewhat larger. The appearance under a hand lens suggests stromata of a Hyphale rather than pycnidia. [Collected in 1927 at Madison and New Glarus.]

Of a collection on Geum made at Sheboygan August 26, 1926, the following notes were made: Spots definite, circular or subcircular, olivaceous with a narrow darker border above, lighter below, 3–5 mm. in diameter, sometimes confluent, conidiophores fasciculate, hyaline, straight, curved or bent, sometimes denticulate near the apex, simple, continuous, often congested, 10–30 x 1–2μ; conidia hyaline, slender, straight, acute, continuous, 25–50 x 1½–2½μ. This has been referred to *Ramularia gei* (Fckl.) Lindau. The species is evidently a variable one ranging from an Ovularia to a Cercosporella type.

In the provisional list all specimens of Aecidium on Helianthus were referred to *Puccinia helianthi* Schw. In *North American Flora* 7: 754, a Wisconsin specimen on

Helianthus was referred to *Nigredo junci* (Desm.) Arth. (*Uromyces junci* (Desm.) Tul.). This form appears to be not uncommon on Helianthus in Wisconsin but no uredinia or telia of *Uromyces junci* (Desm.) Tul. are known to occur in the state but *U. junci-tenuis* Syd. is common and *U. junci-effusi* Syd. is sometimes abundant.

Ramularia dispersa n. sp. Immaculate; conidiophores fasciculate, hyaline, straight, simple, continuous, 20–35 x 3μ; conidia hyaline, catenulate, fusoid to cylindrical, straight, continuous, 10–23 x 2–3 μ. On *Napaea dioica*. Browntown, Wisconsin, September 22, 1926: The white tufts are widely scattered over the lower surface of the unmodified leaves. In this collection the leaves contain many holes apparently due to gnawing insects which suggests that the fungus may have been scattered by insects.

Aecidium trillii Burr. On *Trillium grandiflorum*. Balsam Lake.

Herbarium,
University of Wisconsin,
April, 1927.

NOTES ON PARASITIC FUNGI IN WISCONSIN. XVI

J. J. DAVIS

It is perhaps well to repeat that this series of notes is supplemental to a list of parasitic fungi in Wisconsin published in the Transactions of the Wisconsin Academy of Science, Arts and Letters **17**[2]: 846–984. Names of hosts are according to Gray's New Manual of Botany, seventh edition.

Peronospora urticae (Lib.) DBy. was collected in 1883 at Kirkland (now Devils Lake) by Trelease and at La Crosse by Pammel. These localities are 80 miles apart. No further collections appear to have been made in America except a record by Harkness & Moore of its occurrence in California but there appears to be no specimen extant.

It has recently come to my attention that *Geranium maculatum* was recorded as a host of *Erysiphe polygoni* DC. in the Provisional List while the parasite is really *Sphaerotheca humuli* (DC.) Burr. While looking the matter up in the herbarium I found that the specimen of *Sphaerotheca humuli* (DC.) Burr. on Geranium in Ellis & Everhart *Fungi columbiani continued* 1438 was labeled*Erysiphe polygoni* DC.

Because of the previous use of the name Keithia for a genus of Labiatae by Bentham Maire replaces Keithia Sacc. by Didymascella Sacc. & Maire and makes new combinations accordingly (*Bull. Soc. Nat. Hist. Afrique du Nord.* **18**: 120μ, Abstract in *Review of Applied Mycology* **7**: 59.) Keithia appears to have been used as a generic name still earlier by Sprengel, applied to some phanerogamous plant.

Pycnidia of *Phyllosticta viticola* (B. & C.) Thuem. (*Ph. labruscae* Thuem.) occur in which the sporules are mostly 4–7 x 2–3μ. This may be microconidial rather than immature.

In the 34th Report of the State Museum of Natural History (1881), p. 45, Peck described a leaf parasite of *Apocynum androsaemifolium* under the name *Septogloeum apocyni* n. sp. and gave figures of a spotted leaf and of sporules on Plate I, fig. 2 & 3. Because of the presence of a thin wall surrounding the hymenium this was transferred to Stagonospora in Transactions of the Wisconsin Academy of Science, Arts and Letters 19[2]: 699 (1919). In *Hedwigia* 58: 25 (1917) Bubak, apparently unaware of Peck's publication, described the parasite as *Dearnessia apocyni* n. gen. & n. sp. The thinness of the pycnidial wall and the presence of superficial hyphae hardly seem to be generic characters. Sydow, *Fungi exotici exs.* 749, represents the Fungus.

In the provisional list a parasite of *Gentiana andrewsii* was recorded under the name *Leptothyrium gentianaecolum* (DC.?) Baeumler. Wisconsin specimens were distributed in Ellis & Everhart *North American Fungi 2766* labeled *Phyllosticta* (*Depazea*) *gentianaecola* (DC.). In Ellis & Everhart's *North American Phyllostictas* it was included under the name *Phyllosticta gentianaecola* with *Depazea gentianaecola* given as a synonym. In *North American Flora* 6: 30, it is *Phyllosticta gentianaecola* (DC.) Ellis & Ev. In "Notes" X, pp. 272–3 it was suggested that it might be *Asteroma gentianae* Fckl. In an attempt to clear the matter up material was sent to the European mycologist, Dr. F. Petrak, who thinks it to be distinct and suggests the new binomial **Asteromella andrewsii** nom. nov. The ascogenous state that seems to be connected with it being *Mycosphaerella andrewsii* Sacc. As stated in "Notes" X there is one collection on *Gentiana puberula.*

In July, 1927 a collection was made at Portage that appears to be a better developed state of the parasite that was described in Trans. Wis. Acad. 9: 99 under the name *Septoria brevispora* Ell. & Davis (*Syll. Fungorum* 18: 396). In this collection the spots become sordid white, except the peripheral portion, the pycnidia dark brown with a black ring around the pore and the sporules 15–30 x 2 ½–4μ. On staining, a median division of the cytoplasm appears. The host of the Portage collection was a coarse grass without fructification which may well be *Bromus ciliatus* or a cognate species. In the collections made at Racine, of which there are 4, development may have been arrested by death of the host tissues.

In a collection of Septoria on leaves of what is perhaps *Populus nigra* from Sauk City (Aug. 5, 1927) most of the spots become finally round, white and arid, 1–2 mm. in diameter. The sporules are biseptate only the short ones having but one septum. This seems to be intermediate between *S. Populi* Desm. and *S. musiva* Pk. and is of interest in connection with the suggestion in "Notes" I, p. 83, of a single variable species.

A specimen from this collection was sent to Dr. F. Petrak who identified it as *Septoria populi* Desm. and stated that *S. musiva* Pk. is a form of that species.

In a collection of *Septoria negundinis* E. & E. from Arena the pycnidia are effused over areas that sometimes retain the green color until full maturity of the parasite. Some of the sporules exceed 50μ in length. The hosts are dooryard trees.

A collection made at Carmel, California, by Mrs. Effie S. Spalding communicated by Dr. B. M. Duggar which I refer to this species shows sporules 20–38 x 3–4μ, 3-septate.

In making comparison with specimens of *Septoria davisii* Sacc. in the Davis herbarium the following notes as to size of sporules were found on the packets: "33–40 x 2μ. Type of *Septoria canadensis* Ell. & Davis," "36–80μ long," "30–70 x 2–3μ," "33–52 x 1½–2μ." In the specimen that was being compared they were 33–36 x 2μ. The host appears to be what is now known as *Solidago altissima* L. The parasite is probably not distinct from *Septoria fumosa* Pk.

In addition to the typical form of *Septoria rudbeckiae* Ell. & Hals. *Rudbeckia laciniata* bears a form in which the spots are orbicular to angular, white and arid with a very narrow dark margin, 1–2 mm. in diameter, sometimes confluent. The sporules are straight, 35–70 x 1μ.

Gloeosporium apocryptum Ell. & Ev. was described as having sporules 5–12 x 2½–5μ. Wisconsin collections show sporules up to 17 x 7μ. In germination on a slide dark "appressoria" were produced about 10 x 6μ.

Dr. F. J. Seaver kindly compared *Tuberculina argillacea* Davis ("Notes" XI, p. 293) with *Gloeosporium rubi* Ell. & Ev. (*Journ. Mycol.* 4: 52) and found that they appear to be the same. It is not typical of either genus. The reference to Tuberculina was based largely on its apparent relation to Caeoma.

Dr. Petrak states that a Wisconsin specimen labeled *Ramularia uredinis* (Voss) Sacc. is *Ramularia rosea* (Fckl.) Sacc. (*Ann. Mycol.* 25: 222). It was noted in the 1st and 3d supplementary lists of parasitic Fungi of Wisconsin that it sometimes appeared on leaves of Salix on which no sori of Melampsora were seen. What appears to be the same organism has been collected on Caeoma-infected leaves of *Populus deltoides* as was recorded in "Notes" IV, p. 679. Typical *Ramularia rosea* (Voss) Sacc. is common in Wisconsin on leaves of various species of Salix not bearing Melampsora.

In the transactions of the Wisconsin Academy of Science Arts and Letters **16:** 762–3 *Ramularia paulula* was published as a new species on *Elodes (Hypericum) virginica.* It was afterwards found that the host was probably *Lysimachia thyrsiflora* and the parasite *Ramularia lysimachiae* Thuem., hence it was omitted from the Provisional list.

In the description of *Cladosporium humile* ("Notes" V, 702) it was stated that the conidiophores are epiphyllous. They occur on the lower surface of the spots also.

The record of *Cercospora zebrina* Pass. on *Trifolium dubium* in "Notes" XII, p. 160 was an error. It should be *Cercospora medicaginis* Ell. & Ev. if that is distinct, on *Medicago lupulina.* The collection was made hastily at a junction point while changing trains.

While studying the germination of the spores of leaf smut of Glyceria Bauch found that the sporidia of *Ustilago longissima* (Sow.) Tul. were of two classes as shown by their behavior in conjugation while those of the var. *macrospora* were of three kinds. (*Zeitschr. f. Botanik* **15**: 241 *et seq.*) On morphological grounds Liro considered the variety specifically distinct, proposing for it the binomial *Ustilago davisi.* (*Usilagineen Finnlands* **1**: 80). This illustrates the different conceptions of the limits of a group of organisms that shall be considered a species. When the varietal distinction was first made the host was known as *Glyceria fluitans;* later it was segregated under the name *G. septentrionalis.*

A specimen of *Entyloma compositarum* Farl. on *Lepachys pinnata* collected at New Glarus June 20, 1927 shows unusual development of conidia ranging up to 70 x 2μ.

In "Notes" XIV record was made of the development of Puccinia on *Andropogon furcatus* in the greenhouse in the spring of 1925 using aeciospores of *Aecidium falcatae* Arth. on *Amphicarpa monoica* as the inoculum.

In 1926 similar infection was secured from *Aecidium xanthoxyli* Pk. except that the uredospores were of the *Puccinia pustulata* type. Record of this is made in "Notes" XV issued herewith.

In conversation with Dr. E. B. Mains he told me that he had once infected *Polygala Senega* with *Puccinia andropogonis* but that the return inoculation on Andropogon failed and he did not publish for that reason. In the spring of 1927 two lots of rusted *Andropogon furcatus* that had been overwintered out-doors were anchored in a locality where *Polygala Senega* was growing but where no Aecidium had been seen on it. One lot had been obtained at Blue River and about it no aecia appeared. The other lot came from Dill and around it Aecidium appeared on the Polygala. With these aecia *Andropogon furcatus* was infected in the greenhouse resulting in uredinia and a few telia. The uredospores were of the typical *P. andropogonis* type.

Sheldon reported that he had brought about development of Uromyces on Sisyrinchium by infection from aeciospores of *Aecidium houstoniatum* Schw. on *Houstonia caerulea.* He also reported that he had tried several times to inoculate *Sisyrinchium* with aeciospores from *Houstonia purpu-*

rea both in the field and in the greenhouse but without definite success (*Torreya* 9: 54–5). *Aecidium houstoniatum* Schw. occurs in Wisconsin on *Houstonia longifolia* but no rust has been found on Sisyrinchium although it has been looked for in the vicinity of infected Houstonia. In June, 1927 an attempt was made to infect Sisyrinchium obtained from two sources with Aecidium on Houstonia but although the conditions appeared to be favorable no infection resulted.

In the *Preliminary List of Parasite Fungi of Wisconsin* by William Trelease (*Trans. Wisconsin Academy of Science Arts & Letters* 6 (188), *Uredo* sp. (No. 216) on *Mimulus ringens* and *Aecidium pentstemonis* Schw. (No. 240) on the same host were reported as having been collected at La Crosse by Pammel. I am informed that Dr. Pammel's specimens, which are in the herbarium of Iowa State College, have been examined by Dr. Arthur who concluded that the host is *Epilobium coloratum,* the Uredo *Pucciniastrum pustulatum* (Pers.) Diet. and the Aecidium that of *Puccinia peckii* (De Toni) Kell. The latter has not been recorded as occurring on Epilobium in Wisconsin.

Additional Hosts for Wisconsin

It is customary to add each year another host for Synchytrium in Wisconsin. For 1927 it is *Steironema ciliatum* and the parasite is referred to *Synchytrium aureum* Schroet. In this collection which was made at Blue River, the wall surrounding the sorus is often very irregularly thickened. This may have been due to the character of the season which was very dry.

Albugo candida (Pers.) O. Kuntze
On *Cardamine rhomboidea.* Madison.

Spotting of the leaves of water cress, *Radicula nasturtium-aquaticum,* growing in the waters of springs emptying into lake Wingra at Madison due to *Cercospora nasturtii* Pass. is not uncommon. In 1927 however abundant leaf spotting occurred which was due to *Peronospora parasitica* (Pers.) Tul.

Sphaerotheca humuli (DC.) Burr.
On *Geum strictum.* Sauk City.

Erysiphe cichoracearum DC.
On *Lactuca spicata.* Madison.

Microsphaera alni (Wallr.) Wint. (*M. elevata* Burr.)
On *Catalpa* (cult.) Cudahy. A. C. Burrill.

Acanthostigma occidentale (E. & E.) Sacc.
Stylosporous state on *Artemisia ludoviciana.* Token Creek. The stylospores are about 5 x 2μ.

Stagonospora intermixta (Cke.) Sacc.
On *Agrostis alba.* La Valle. In this collection the pycnidial wall is of uniform thickness, the 7-septate sporules 43–48 x 3½μ.

Septoria caricinella Sacc. & Roum.
On *Carex straminea* and *C. Bebbii.* New Glarus.

Septoria violae West.
On *Viola blanda.* Hollandale.

Septoria lysimachiae West.
On *Lysimachia quadrifolia.* La Valle. Scanty and poorly developed in this collection.

Colletotrichum graminicolum (Ces.) Wilson.
On culms of *Cinna arundinacea.* Arena.
On *Sorghastrum nutans.* Browntown.
But few sporules in this collection. The spots are purple bordered.

Marssonina coronaria (Ell. & Davis) Davis. (*Marsonia coronariae* Sacc. & Dearn.)
On *Pyrus ioensis.* Trempealeau and Highland.

Ramularia decipiens Ell. & Ev.

On *Rumex obtusifolius.* Browntown.

Fusicladium effusum Wint. var. *carpineum* Ell. & Ev.
On *Carpinus caroliniana.* Hollandale.
[Demaree finds that the conidia of *Fusicladium effusum* Wint. on Carya are catenulate and refers the species to Cladosporium with a new description (*Journ. Ag'l Re-*

search 37: (86) The form on Carpinus appears to be of the same character.]

Cercospora helianthi Ell. & Ev.

On *Helianthus strumosus.* Browntown. In this collection the conidiophores are hypophyllous, tortuous, multiseptate, ranging up to 200μ in length.

Isariopsis albo-rosella Sacc.

On *Stellaria aquatica.* South Wayne and Gratiot. Abundant at the latter station but not well developed at the time of collection. It was thought to be *Graphiothecium pusillum* (Fckl.) Sacc. until septate conidia were found.

In 1911 *Puccinia graminis* Pers. was observed on a single plant in a colony of *Glyceria grandis* near Butternut in northern Wisconsin. In 1927 this experience was repeated at New Glarus in southern Wisconsin. At Blue River a plant of *Leersia virginica* was found bearing *Puccinia impatienti-elymi* Arth. (Klebahn) = *P. impatientis* Arth. = *P. elymi-impatientis* Davis. This rust is abundant in the locality on Elymus but in only the single instance has it been found on Leersia although 3 species of the genus occur there and it has been a favorite collecting ground in previous years. There appears to be no record of its occurrence on this host elsewhere. Such occurrences may lead one to surmise that development of a species on a new host may occasionally take place and that this may sometimes be followed by adaptation, physiological changes due to the new substratum resulting in isolation followed in time by morphological differentiation and the development of a new species.

Acerates floridana is recorded as an aecial host of *Dicaeoma jamesianum* (Pk.) Arth. = *Puccinia bartholomaei* Diet. in Wisconsin in *North American Flora* 7: 320.

Puccinia seymouriana Arth.

Aecia on leaves and stems of *Asclepias ovalifolia.* New Glarus.

Puccinia peckii (De Toni) Kell.

Aecia on *Oenothera rhombipetala.* Mazomanie.

Solidago graminifolia should be included in the list of aecial hosts of *Puccinia extensicola* Plowr. in Wisconsin.

Chrysomyxa pyrolae (Pers.) Diet.
Uredinia on *Pyrola americana.* Friendship.

Coleosporium solidaginis (Schw.) Thuem.
On *Callistephus chinensis* (cult.)
Oconto (A. C. Burrill)

ADDITIONAL SPECIES

Not hitherto recorded as occurring in Wisconsin.

Investigation of host relations of obligate fungous parasites has shown that they are usually adapted to the kind of host upon which they are found. That the adaptation may be relative rather than absolute has also been shown, and that it is not necessarily accompanied by morphological differentiation is well known. By some mycologists new species have been proposed based only upon adaptation to a particular species of host. The practice of considering these as physiological races seems the better one and hence they are not recorded in these notes in which the hosts have already been given.

Peronospora oxybaphi Ell. & Kell.
On *Oxybaphus nyctagineus.* Browntown and Brodhead along the railroad. The conidia range up to 30μ in length and 22μ in breadth and are ovate in outline.

At a station near Friendship a few plants of *Melampyrum lineare* were found, only 3 or 4 as I remember, and none were found elsewhere in that locality. On the young upper leaves of these plants was a parasite regarding which the following notes were made: Forming a sordid gray coating on the lower leaf surface; conidiphores 300–400μ long, 3–4 times branched, usually dichotomously, but sometimes the branches are at an obtuse or even a right angle, ultimate branchlets short, straight, acute, divergent; concidia fuscous, elliptical, acute at base, 24–36 x 20μ. No oöspores were found.
Plasmopara melampyri Bucholtz I know only from the description in Saccardo: *Sylloge Fungorum* **21**: 861 but

the Wisconsin plant seems to be referable to that species. Bucholtz appears to have been in doubt as to whether it should be placed in Peronospora or Plasmopara. To the writer it furnishes additional evidence that they are congeneric and that the latter was given generic rank before the evidence was all in. As this parasite has apparently been found in the single locality in Russia and the very restricted station in Wisconsin only, one might suspect that it is well on the way toward extinction. However recrudescences have been known to occur in such cases.

[This was collected the following year at Radisson. As in the previous collection it was confined to the lower surface of the upper leaves and would escape detection when the hosts were observed from above as the infected leaves, at least at the time of collection, were not changed in appearance by the presence of the parasite. The germination of the conidia has not been observed and oöspores have not been seen.]

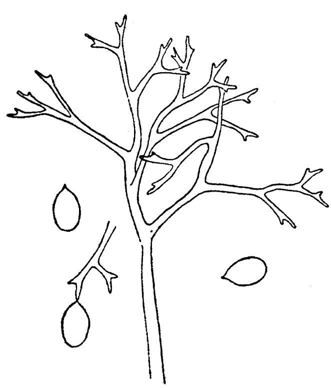

FIG. 1. A conidiophore and three conidia of *Plasmopara melampyri* Bucholtz. Drawn by E. M. Gilbert with the aid of camera lucida.

The lower surface of the older leaves of the same plants of the Friendship collection bore *Ramularia melampyri* Ell. & Dearn. I have not seen a specimen of *Fusidium melampyri* Rostr. but the description suggests that it is the same species as the one described by Ellis & Dearness.

What has been known as *Ascochyta pisi* Lib. has been divided by Linford & Sprague into 2 species one retaining the name and the other a pycnidial state of *Mycosphaerella pinodes* (Berk. & Blox.) Stone with which the typical *Ascochyta pisi* Lib. is not connected. They also found a third form which they designated temporarily *Mycosphaerella pinodes* microform (?) (*Phytopath.* **17**: 390–91.)

[For the "microform" the binomial *Ascochyta pinodella* n. sp. has been proposed by Leon K. Jones (N. Y. State Ag'l. Exp. Station, Geneva, Bull. 547, p. 10) and for the pycnidial stage of *Mycosphaerella pinodes, Ascochyta pinodes* (Berk. & Blox.) n. comb. (*loc. cit.* p. 4.)]

While examining leaves of *Anemone canadensis* for the presence of oöspores of *Plasmopara pygmaea* it was found that in addition to the oöspores there were present pycnidia about 100μ in diameter containing hyaline oblong sporules 18–30 x 3–7μ 1–2 septate. Whether or not this is *Stagonospora anemones* Pat. I do not know.

Septoria polygalae Pk.

On *Polygala Senega.* New Glarus.

This name was given by Peck to a species occurring on *Polygala pauciflora.* Subsequently he collected a form on *Polygala Senega* bearing Aecidium also to which he gave the name *Septoria consocia.* As described this differs from the former in its shorter sporules which otherwise are of the same character. On the Wisconsin collection there is no Aecidium and the sporules are intermediate in length (23–33 x ½–1μ) as between the two descriptions.

Septoria calystegiae West.

On *Convolvulus arvensis.* Madison.

Septoria polemonii Thuem. (*S. polemoniicola* Ell. & Mart.)

On *Polemonium reptans.* Gratiot and Token Creek.

S. polemoniicola Ell. & Mart. appears to have been separated mostly because of the small white spots but European specimens bear similar spots. Ellis & Martin apparently knew von Thuemen's species from the description only.

While some kinds of plants are infected by various fungi others are seldom found to be attacked. In Wisconsin no parasite had been seen on Lithospermum. In July 1927, however, a few spotted leaves of *L. canescens* were observed near Portage. The spots are dark brown, more conspicuous below, subangular, 1–3 mm. in diameter. There are small spore bodies, usually near the periphery of the spot on the upper surface and few in number bearing tufts of hyaline conidia 40–60 x 2/3μ which are usually curved, often strongly so. The better developed spore bodies appear to be imperfectly formed pycnidia. It seems possible that this was a chance infection by a Septoria that normally develops on another host. I do not now recall whether the infection was confined to a single plant but the small number of infected leaves suggests that it may have been. For the purpose of filing this has been labeled *Septoria lithospermi* nom. herb.

Colletotrichum trifolii Bain is reported as occurring in Wisconsin by John Monteith, Jr., in U. S. Department of Agriculture Technical Bulletin No. 28.

Gloeosporium achaeniicola Rostr.

On epicarp of *Heracleum lanatum*. Mineral Point. The type of this species was on fruit of *Pastinaca sativa.*

Cylindrosporium pimpinellae C. Massal. var. *pastinacae* Sacc.

On *Pastinaca sativa.* Gratiot.

In this collection the conidia are mostly 60–70 x 3–4μ curved, tapering both ways from the middle, becoming 1–3 septate.

Didymaria puncta n. sp.

On elongate light brown to sordid white areas; conidiophores borne on the outer aspect of globose brownish black tubercles, congested, hyaline varying from 15 x 2–3μ to obsolete; conidia apical, hyaline, straight, long fusoid, acute, 20–30 x 3μ developing a median septum. On stems and bracts of *Sisyrinchium campestre.* New Glarus, Wisconsin, June 17, 1927. The tubercles are closely spaced, 40–60μ in diameter. The conidia fall away readily and it was not determined whether they are catenulate or not.

From collections on leaves of *Saxifraga pennsylvanica* made at Portage, June 6 and 8, 1927 the following notes were made: Spots circular, brown sometimes more or less tinged with purple, becoming cinereous with the development of conidia and often zonate above, uniformly brown below, 4–8 mm. in diameter; conidiophores arising from dark tuberculoid stromata, congested, hyaline, straight or somewhat flexuose above, often subulate, 10–30 x 2–4μ; conidia hyaline, filiform, straight or lax, 30–100 x 1–2μ. I do not doubt that this is the species collected at Dover, Norway to which Rostrup gave the name *Cercosporella saxifragae* which I know only from description. There is a discrepancy in the length of the conidiophores which are described as being long but that is a character that cannot be stressed in this group.

Of a collection on leaves of *Tanacetum vulgare* from a garden in Highland the following notes were made: Spots becoming definite and black; conidiophores amphigenous, hyaline, fasciculate, simple, mostly straight and continuous, 20–40 x 3–4μ; conidia hyaline, straight, cylindrical but usually with a slight taper, obtuse at each end, 24–43 x 3½–5μ. On referring to the description of *Ramularia tanaceti* J. Lind in the *Sylloge Fungorum* the statement was met that the conidia are acute at each end. In Rabenhorst *Kryptogamenflora* Lindau gave a description which he stated was more complete than Lind's and resulted from examination of original material. This description is the same as the one in the *Sylloge* including the statement that the conidia are acute at each end. In the original description by Lind (*Ann. Mycol.* 3: 431), however, the conidia are described as being obtuse at both ends as they are in the Wisconsin collection. There seems to be no question of the identity of the Wisconsin parasite and *Ramularia tanaceti* J. Lind. The similarity in the names of the three mycologists Lind, Lindau and Lindroth sometimes leads to confusion. For instance in Oudemans' *Enumeratio Systematica Fungorum* this species is attributed to Lindroth.

Cercospora thaspiicola n. sp.

Spots pale alutaceous becoming sordid white, angular, limited by the veinlets, with a narrow brown border, 2–5 x

1–2 mm.; conidiophores amphigenous, fuligenous tinted, caespitose, straight with an oblique apex and a shoulder, simple, continuous, 35–50 x 4–5μ; conidia hyaline, fusoid-cylindrical, obtuse, straight or slightly curved, 1–3 septate, 37–73 x 4–6μ. On *Thaspium aureum.* South Wayne, Wisconsin, June 27, 1927. Ellis & Everhart, *North American Fungi 2585* is labeled *Cercospora thaspii* n. sp. On leaves of *Thaspium trifoliatum* Wilmington, Delaware, November 1889. A. Commons. Apparently no description was ever published. The specimen shows circular or sometimes angular brown spots which become white and arid with a brown border 1–2 mm. in diameter. The conidiophores are in small fascicles, erect or diverging, straight or but little flexuose, deep brown, pluri-septate, 50–100 x 5–6μ. As one might expect of a specimen collected so late in the season and so long ago, no conidia were found. In Gray's Manual of Botany, edition 5, which was in use in 1889, *Zizia cordata* DC. was referred to *Thaspium trifoliatum* as var. *apterum* and it is a question as to whether *N. A. F. 2585* is on Thaspium or Zizia and in the absence of conidia what its relation may be to *Cercospora ziziae* Ell. & Ev. It may easily be that collections of a species made in June and in November would show differences but there does not seem to be justification for stating that *N. A. F. 2585* and the Wisconsin collection are conspecific.

Although *Puccinia muhlenbergiae* Arth. & Hol. has been known in Wisconsin no Aecidium on Malvaceae had been seen until 1927 when *Aecidium napaeae* Arth. & Hol. was collected on *Napaea dioica* at Gratiot, New Glarus, Browntown and South Wayne. These localities are in southern Wisconsin. The host seems to be spreading along the railroads especially where they pass over low ground and are ballasted with cinders.

Aecidium sparsum n. sp.

Pycnia hypophyllous, scattered, brown; aecia hypophyllous, scattered, ¼–1/3 mm. in diameter; peridium white, lacerate, the lobes reflexed and caducous; spores yellow globose, thin-walled, finely and sparsely verrucose, 18–22μ in diameter. On *Galium tinctorium* on bottom lands of the

Wisconsin river opposite Sauk City, July 2, 1925 (Weber & Davis,) July 11, 1927. The distribution of the aecia suggests systemic infection but there is no distortion or discoloration of the host.

Herbarium,
University of Wisconsin,
April, 1928.

NOTES ON PARASITIC FUNGI IN WISCONSIN. XVII

J. J. DAVIS

H. Sydow has proposed that *Phacidium balsameae* Davis ("Notes" VIII, p. 424) be made the type of a new genus Stegopezizella. (*Ann. Mycol.* 22 : 392)

To the description of *Peziza* (*Mollisia*) *singularia* Pk., afterwards referred to Pseudopeziza, was added the suggestion "Perhaps a form of *Pseudopeziza ranunculi* Fckl." (35th Report, p. 142). This is doubtless the case and that is a form of *Fabraea ranunculi* (Fr.) Karst. Septate spores have been seen in Wisconsin material. The common host in Wisconsin is *Ranunculus pennsylvanicus* but it occurs also on *R. septentrionalis.*

Marsonia baptisiae E. & E. on *Baptisia leucantha,* founded on a specimen from Iowa, was published in the *Bulletin of the Torrey Botanical Club* 24: 291 [1897] with the statement that the conidia become "faintly uniseptate". In "Notes" II, p. 103, this was recorded as occurring in Wisconsin with the statement that "septation of the sporules seems doubtful". In "Notes" XIV p. 186 *Ascochyta baptisiae* n. sp. was described with conidia uniseptate or occasionally with 2 or 3 septa. In 1928 a collection was made at Mazomanie in which the sporules are predominantly 2–3 septate. Re-examination of the specimen referred to *Marssonina baptisiae* (E. & E.) shows that the sporules are borne in pycnidia with walls about two cells thick. It is evident that the three collections represent degrees of development of the same parasite. I have not seen an authentic specimen of *Marsonia baptisiae* E. & E., but the description indicates that it is the same as the Wisconsin species. I am therefore labeling all of the specimens **Stagonospora baptisiae (E. & E.) n. comb.**

A parasite of *Shepherdia canadensis* was recorded in "Notes" II, p. 105, under the name *Cylindrosporium shep-*

herdiae Sacc. After examination of a collection from Idaho Dearness changed the name to *Septoria shepherdiae* (Sacc.) Dearn. (*Mycologia* 20: 238). With the Wisconsin record was a suggestion that this is close to *Septoria argyraea* Sacc.

In the *29th Report of the State Botanist of New York* a fungus on living leaves of *Trillium erythrocarpum* was described under the name *Vermicularia concentrica* P. & C. n. sp. The description was followed by the statement that Judge Clinton had sent in a variety on *Viola rotundifolia.* In the *Sylloge Fungorum* 3: 232, Saccardo changed the name to *Vermicularia peckii* Sacc. and designated the form on Viola var. *violae–rotundifoliae.* In the Report of the State Botanist for 1919 the variety was raised to specific rank as *Vermicularia violae–rotundifoliae* (Sacc.) House. In the *Botanical Gazette* 26: 96–97 Miss Stoneman described and figured *Volutella violae* n. sp. on *Viola cucullata.* In the Wisconsin "Notes" XI, p. 297 *Colletotrichum violarum* n. sp. was recorded on *Viola scabriuscula.* This has since been found on other species of Viola in Wisconsin. Examination of authentic material from Dr. House and of Miss Stoneman's description and figures indicates that the Wisconsin species is not distinct and that all of them should be referred to Colletotrichum because of their acervulous character. I am therefore labeling them **Colletotrichum violae–rotundifoliae** (Sacc.) n. comb. This accords with the results of Miss Duke's investigation in which she found that Vermicularia is not distinct from Colletotrichum (*Trans. Brit. Mycol. Soc.* 13[3]). I quite agree with her that Colletotrichum, which was properly described, should be retained instead of Vermicularia as the name of the genus.

In "Notes" III, p. 263 a collection on *Streptopus roseus* was referred to *Vermicularia liliacearum* West. There are also Wisconsin specimens on *Uvularia grandiflora* (Nelson Dewey State Park and Maiden Rock), *Oakesia sessilifolia* (Plover and White Lake) and *Smilacina stellata* (Woodman). All of these are on leaf spots and I am now designating them **Colletotrichum peckii** (Sacc.) n. comb.

Of Ellis & Everhart *North American Fungi 2778, Vermicularia helianthi* E. & K. n. sp. on *Helianthus rigidus,* Manhattan, Kan. autumn 1887, W. T. Swingle I have seen no description.

Colletotrichum helianthi Davis, "Notes" I, p. 88 is apparently the same parasite.

In a collection of *Cladosporium humile* Davis on *Acer saccharinum* the development is on the peripheral portion of Rhytisma spots sometimes extending on to the ascocarp. The collection was made at Sauk City September 6, 1928.

In the description of *Cercospora viciae* Ell. & Hol. (*Journ. Mycol.* **1**: 5 & 39) the conidiophores are said to be "short, 25–30×3–4μ". The Wisconsin specimens that have been referred to this species bear conidiophores up to 80μ long and the conidia sometimes attain 70μ in length. The parasite is rather common on *Lathyrus venosus, L. ochroleucus* and to a less extent on *L. palustris* in the northern part of the state. There is but one specimen on Vicia (*V. caroliniana*) which is from southeastern Wisconsin and bears equally long conidiophores.

The smut of *Polygonum sagittatum* recorded in the provisional list under the name *Sphacelotheca hydropiperis* (Schum.) DBy. is separated from that species by Liro and given the name *Sphacelotheca granosa* Liro. He gives as a distinguishing character the more prominent verrucosity of the spore wall. (*Ustilagineen Finnlands* **I**: 148–150)

In one of the "Notes" reference was made to an Aecidium on *Linaria canadensis* with the suggestion that as the host is a Scrophulariacea the Aecidium is probably connected with *Puccinia andropogonis* Schw. Attempts to infect *Andropogon furcatus* with the aeciospores in the greenhouse have failed, however, when the conditions appeared to be favorable for infection.

In June, 1928 plants of *Amphicarpa monoica* and *Polygala Senega* were exposed to infection from Puccinia on *Andropogon furcatus* in the greenhouse. Abundant aecia were produced on the Polygala but none on the Amphicarpa. The telia were obtained at New Glarus near *Polygala Senega* plants that had borne aecia earlier in the season. As far as the experiments have gone they suggest that *Puccinia andropogonis* Schw. is specialized as to aecial hosts but perhaps not as to telial.

ADDITIONAL HOSTS

Peronospora candida Fckl. *(P. androsaces* Niessl). On *Androsace occidentalis.* On a hill opposite Prairie du Sac.

Plasmopara viticola (B. & C.) Berl. & De Toni. On *Vitis bicolor.* Platteville.

Claviceps purpurea (Fr.) Tul. Sclerotia on *Glyceria borealis.* Haugen.

Phyllachora graminis panici Shear. On *Panicum tennesseense.* Sauk County.

Septoria bromi Sacc. On *Bromus incanus.* Couderay. In this collection the more or less depressed pycnidia are 100–165 x 60–100μ, the sporules filiform, straight or but little curved, 37–60$\times$1–1½μ.

Septoria astragali Rob. On *Vicia americana.* Radisson. In this collection the pycnidia are very imperfect and the sporules grow out to a length of 120–200μ resembling Cylindrosporium. This appears to be but the second collection in the state, the first having been reported by Trelease in 1884.

Of a collection on leaves of *Solidago altissima* made at Mazomanie, Sept. 20, 1928 the following notes were made: Spots subcircular, brown becoming cinereous above, 3–5 mm. in diameter, forming large areas through death of the intervening tissue; pycnidia epiphyllous, not prominent, succineous, globose, wall thin, of thin flat polygonal cells, 80–100μ in diameter; sporules hyaline, straight, cylindrical with rounded ends, developing a median septum, 20–27$\times$6–7μ. Shorter continuous sporules are assumed to be immature. This is referred to *Ascochyta compositarum* Davis *(Trans. Wis. Acad.* 19^2: 700).

A collection of the aecial stage of *Puccinia bartholomaei* Diet. on *Acerates longifolia* made by Pammel at La Crosse in 1883 appears to be the only one of that stage that has been made in Wisconsin. [This was collected in 1929 on *Acerates lanuginosa* near Prairie du Sac.]

Puccinia rubigo-vera (DC.) Wint. (*P. elymi* West., *P. agropyri* E. & E.). On *Bromus incanus*. Couderay. In this collection the sori are epiphyllous and small and most of the teliospores distorted.

Sclerotium deciduum Davis. On *Bidens frondosa*. Radisson.

ADDITIONAL SPECIES

Dothichloe atramentaria (B. & C.) Atk.
On culms of *Calamagrostis canadensis* in a cranberry marsh at Cranmoor (E. E. Honey).

Phyllosticta limitata Pk.
On *Pyrus Malus*. Lancaster. (V. H. Young & J. J. Davis.)

Phleospora mori (Lev.) Sacc.
On *Morus alba*. Madison. In all of the specimens of this parasite that I have seen the conidia are borne externally on a stroma of subcuticular origin and they might be referred to Cylindrosporium.

In August 1928 small collections were made at Platteville and Shullsburg of a parasite on leaves of *Abutilon Theophrasti* from which the following notes were made: Spots circular, alutaceous with a dark border, alike on both surfaces of the leaf; when young 1–3 mm. in diameter, with maturity becoming more irregular in outline, up to 6 mm. in length and becoming lacerate; pycnidia epiphyllous, depressed-globose, variable in size up to 200μ in diameter with a black bordered pore up to 30μ across; sporules hyaline, straight, continuous, $6–16 \times 2–3\frac{1}{2}\mu$. It may be that this is *Ascochyta abutilonis* Hollos, in which the septation of the sporules is said to come late, of which I have not seen an authentic specimen.

Leptostroma pinastri Desm.
On *Pinus Banksiana*. Camp Douglas.

Sphaceloma symphoricarpi Barrus & Horsfall. (*Phytopath.* 18:799.)
On *Symphoricarpos racemosus* (Cult.). Madison. The spots are abundant on the fruit but acervuli are rare.

The preservation of specimens of the more delicate Hyphales is often unsatisfactory because of the falling away of the conidia and to a much less extent, the conidiophores. When on flat leaves and carefully treated the pressure tends to hold them in place and the detached ones do not wander far. From cylindrical surfaces, however, they disappear. This is by way of apology for calling attention to two species of which the material in hand leaves something to be desired.

Cercospora eleocharidis n. sp.

Globose, black, subepidermal, stromatoid bodies which sometimes extend into the epidermis from which spring fascicles of fuligenous fertile hyphae which reach the surface and usually extend 3–15μ beyond; conidia apical, hyaline, narrow cylindrical, straight or somewhat curved, 30–70 $\times$ 2μ. On more or less extensive dying and dead areas on culms of *Eleocharis palustris.* Brill, Wisconsin, July 23, 1928. This has been observed in Wisconsin for a number of years but the collections have hitherto been discarded when they came from the press because the conidia had fallen away.

Cercospora junci n. sp.

Black, scattered, intraepidermal, stromatoid bases 20–30μ wide; conidiophores fuligenous tinted, nodulose, 15–30 $\times$ 3–4μ; conidia subolivaceous, obclavate-cylindrical, acute, straight, 60–75 $\times$ 4–5μ. On dying and dead areas or entire leaves of *Juncus brevicaudatus.* Brill, Wisconsin, July 23, 1928.

Cercospora setariae Atk.

On *Setaria glauca.* Browntown.

Cercospora parvimaculans n. sp.

Spots brown, angular, ½–1½ mm., often confluent and sometimes with a white center on the upper surface; conidiophores in small scattered fascicles or solitary, hypophyllous, more or less fuligenous, becoming tortuous, denticulate, and septate, 50–100 $\times$ 3–5μ; conidia subhyaline, straight or curved, cylindric-obclavate to flagelliform, 100–180 $\times$ 4–6μ. On leaves of *Solidago serotina.* Sauk City, Wisconsin, September 6, 1928, type. Other collections are from Lone Rock, Blue River and Wauzeka July and August 1921, but no description was published.

Cercospora silphii Ell. & Ev.

On *Silphium laciniatum,* Shullsburg. *Silphium terebinthinaceum,* Madison. In these collections the spots are purplish-brown to black and the tufts inconspicuous. The conidiophores are often shorter than those of the type as described. A form on the former host was designated var. *laciniatae* by Tehon & Daniels (*Mycologia* 19: 128).

Coleosporium terebinthinaceae (Schw.) Arth.

Uredinia and a few telia on *Silphium perfoliatum.* Lancaster. In this collection the uredospores are 23–40μ in length. That this species is a permanent member of the Wisconsin flora is questionable.

Uromyces alopecuri Seym.

On *Alopecurus geniculatus aristulatus.* Haugen.

Puccinia physostegiae Pk. & Cl.

On *Physostegia parviflora.* Abundant at a station in the bottom lands opposite Sauk City in 1928 attacking especially the upper leaves and the inflorescence, destroying the flowers.

While the fungous growths on "honey dew" on leaf surfaces are not parasites their effects are probably ill. An interesting form that occurs in Wisconsin on leaves of various plants is apparently the one to which Woronochin gave the name *Sclerotiomyces colchicus* (*Ann. Mycol.* 24: 234). The orbicular flattened sclerotia strongly resemble perithecia.

Herbarium,
University of Wisconsin,
April, 1929.

INDEX TO PARASITES AND HOSTS REFERRED TO IN NOTES XV, XVI, XVII

The names of Fungi are in italics.

A CYTOLOGICAL STUDY OF FERTILIZATION IN ACHLYA HYPOGYNA COKER AND PEMBERTON

George Olds Cooper

The question of fertilization in the Saprolegniaceae has long aroused interest among botanists. Pringsheim (1855), while he did not actually observe fertilization, believed that it took place. Later workers, de Bary (1884), Humphrey (1892), Hartog (1892–1895) studying various genera, came to the conclusion that fertilization did not occur. However, Trow (1895, 1904) disagreed with Hartog and showed without doubt that fertilization does occur in some species of the Saprolegniaceae.

Since Trow's work further evidence that fertilization does occur has been demonstrated by Claussen (1908), Mücke (1900), Kasanowsky (1911), Carlson (1925), and Couch (1925).

Materials and Methods

The fungus used as a basis for this study was secured from dead minnows in Tomahawk Lake, Wisconsin. Cultures were grown on boiled corn endosperm in distilled water. As the early cultural studies were made in the field, it was impossible to make single spore isolations; therefore growth from single sporanges was taken as a basis for classification. Cultural studies were made from time to time, and from Coker's "Classification of the Saprolegniaceae" (1925) the species was identified as *Achlya hypogyna* Coker and Pemberton. This determination has been since verified by Mr. J. V. Harvey.

The material was preserved in formol-acetic-alcohol, imbedded by the paraffin method, and sections were cut to 5 microns in thickness. Overstaining with Haidenhain's iron-alum haematoxylin with light green as a counter stain gave the best results.

Observation and Discussion

In *Achyla hypogyna* Coker and Pemberton, the oogones arise from hyphae on short lateral branches of the mycelium. In the formation of the oogone there is a streaming of the cytoplasm into the hyphal tip, forming in it a marked swelling. The streaming continues until the swelling has caused the hyphal tip to become almost spherical. A cross wall is now laid down at the base of this spherical tip and the young oogone is thus formed. The cytoplasm at this stage is multinucleate; conspicuous vacuoles are present, surrounded by cytoplasm containing granules (mitochondria) of varying size and shape. A small dark body resembling a nucleolus was observed in each of the nuclei. This body seems to be identical with that described by Hartog as a chromatin body, by Trow as a combination of a chromosome and a nucleolus, by Davis, Claussen, Mücke, and Carlson as a nucleolus. Shortly, there appears a definite vacuole near the center of the oogone. As this vacuole increases in size many of the nuclei migrate to the periphery of the oogone and show signs of degenerating. The remaining nuclei are found near the vacuole and vary as to number, from a few to as high as sixteen in some oogones. These nuclei undergo only one mitotic division (fig. 1). Many of the nuclei formed as a result of this division degenerate, leaving seemingly only those that are to function as nuclei of the eggs. These remaining nuclei enlarge slightly and are readily recognized (fig. 2). That there is only one division occurring within the oogone agrees with the conclusions of Davis, Claussen, Mücke, Kasanowsky, and Carlson in regard to closely related species. Trow (1904) describes the occurrence of two divisions in the oogone, the second of which he believed to be a reduction division.

The central vacuole after mitosis enlarges greatly by furrowing the cytoplasm (fig. 2). Further furrowing extends to the periphery of the oogone, leaving apparently small rounded portions of the cytoplasm extending into the vacuole. These partially rounded cytoplasmic masses are known as egg initials and their number depends upon the number of nuclei that remained following the divisions and subsequent degeneration of some of the nuclei. This is evidently the case, because in each of the initials only one of these nuclei was found. Occasionally, however, an egg was found containing two nuclei. In no instance were extra nuclei found scattered about in the egg, unless they were degenerating (fig. 3). Davis found in these egg initials a body which he termed a coenocentrum and which he believed was instrumental in the rounding up of the eggs. He referred to this rounding up as the "balling" of the cytoplasm. This body acted as a dynamic center which drew the cytoplasm to it and rounded it up into a spheroid mass. Miss Carlson and the writer found what might be termed a coenocentrum, but observed it only a few times. Claussen also mentioned such a body. From continued observation of the formation of the eggs and the infrequency of the finding of the "coenocentrum," the writer is inclined to the belief that the coenocentrum is not the active agent. This body was observed in eggs that had nearly rounded up. It lay partially surrounding the nucleus and several fibrils radiated from it. The agent that is instrumental in the formation of the eggs is the central vacuole, according to the present writer, and by its continual furrowing of the cytoplasm the eggs are cut out. Later, when the vacuolation has gone to completion and the egg initials have rounded up, they come to lie close together so that their sides appear to be in contact. Shortly afterwards they separate and remain suspended in the liquid in the oogone.

During the formation of the eggs in the oogone, antherids have been approaching the oogone from the neighboring hyphae. The name of this species was derived from the fact that the antheridial branch often arises from the hypha immediately beneath the oogone and attaches itself to it. Antherids were observed to attach themselves to the oogones after the formation of the eggs, but more frequently at the stage of the egg initial. The development of the male gametes within the antherid is very similar to that in the oogone. After the cytoplasm has streamed to the tip of the antherid, a cross wall is laid down. The cytoplasm is multinucleate and, as in the oogone, many of the nuclei migrate to the periphery and degenerate. The remaining nuclei undergo one mitotic division and many of these nuclei also degenerate. Those nuclei remaining were scattered in the cytoplasm and seem to enlarge slightly.

The antherid, upon coming in contact with the oogone, may indent the oogone wall; whether it finally ruptures the wall and discharges its contents into the oogone was not observed. As is more often the case, the antherid adheres to the oogone and sends one to several fertilization tubes through the oogone wall. These fertilization tubes grow until they come in contact with one or more eggs. However, when a fertilization tube comes in contact with an egg, other fertilization tubes from this same antherid either grow to neighboring eggs or indicate signs of collapse. The fertilization tubes vary as to length and width. Some have walls that are fairly smooth, while others are quite irregular. Several nuclei are often present within them and the nucleus that is most terminal appears slightly larger than the others and is generally the nucleus that functions as the male gamete nucleus. Upon the discharge of the male gamete nucleus into the egg the other nuclei in the fertilization tube soon showed indications of degeneration.

Previous workers observed that the wall of an oogone in a number of species varied in thickness. The oogone wall in surface view, appears to be made up of many circular thickened plates at the intersection of which the areas were thin-walled. In section view, this gave the appearance of thickened areas separated by a thin membrane. It was believed for a long time that the fertilization tube penetrated the thinner areas only, due probably to some chemotactic stimulus. Couch, in his studies with the water molds, has observed the fertilization tubes penetrating the thickened areas as well as the thinner ones, and so believes that there is no ground for the assumption that the fertilization tubes penetrate the thinner areas only.

Before the fertilization tube is in contact with the egg it may contain several nuclei, the more terminal one of which has enlarged. This tube continues to grow until it comes in contact with the egg and the terminal nucleus enlarges still more and in doing so probably ruptures the tip of the fertilization tube (fig. 4). The male gamete nucleus, as it is now recognized, can be seen within the egg (fig. 5). The female gamete nucleus is also present and is recognized by the fact that it is slightly larger and denser. A nucleolus was not observed in either of the gamete nuclei. It was not uncommon to find the female gamete nucleus not in the center of the egg. In these preparations, while it may not be characteristic of the species, the writer observed that the male gamete nucleus was invariably discharged into the egg at the side farthest away from the female gamete nucleus.

The male gamete nucleus, upon its discharge into the egg, migrates to the female nucleus and evidently unites with it (fig. 6). The nuclei were easily recognized, one slightly over-lapping the other. The penetration path left by the male gamete nucleus as described by Couch in *Leptolegnia caudata,* was not observed. Upon the union of the gamete nuclei the egg becomes a zygote (fig. 6). A wall now appears about the zygote, the cytoplasm becomes finely vacuolate and often several oil bodies of varying size are present. The zygote when mature is slightly contracted.

The results of this cytological investigation seem to definitely establish the presence of fertilization in *Achlya hypogyna* and add, therefore, an eighth species of the Saprolegniaceae wherein fertilization has been observed. Up to the present, fertilization has been observed in three Saprolegnias by Trow (1895) and Claussen (1908); in seven Achlyas by Trow (1899, 1904), Davis (1905), Mucke (1908), Carlson (1929), and by the writer; in an Aphanomyces by Kasanowsky (1911); and in Leptolegnia by Couch (1925). Owing to the large number of genera and species in the Saprolegniaceae, there is opportunity for further work to be carried on in this field.

The writer wishes to express to Dr. E. M. Gilbert his appreciation for the advice and encouragement received during the course of the work.

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Explanation of Plate 2

All figures were drawn with a camera lucida and with a Leitz 4-ocular and a 1/12 oil immersion. Magnification 1500.

Contents of the oogones were drawn with a Zeiss 12 compensating ocular and a 3 mm. aprochromatic oil immersion.

FIG. 1. Young oogone with the nuclei in the metaphase; degenerate nuclei at the periphery.

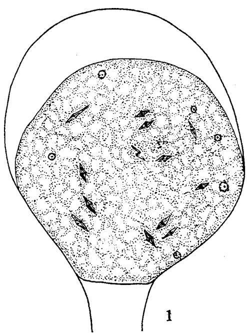
FIG. 2. Central vacuole prior to the formation of the egg initials.

FIG. 3. Oogone containing four egg initials; antherids present.

FIG. 4. The approach of the fertilization tube containing the male gamete nucleus to the egg.

FIG. 5. The fertilization tube has discharged the male gamete nucleus into the egg.

FIG. 6. The male gamete nucleus about to be discharged from the fertilization tube. Zygote; gamete nuclei in contact.



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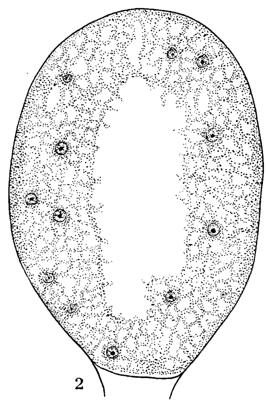

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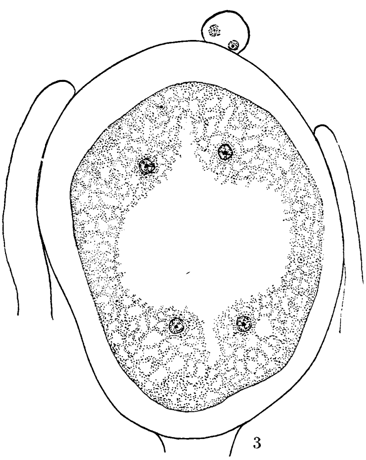

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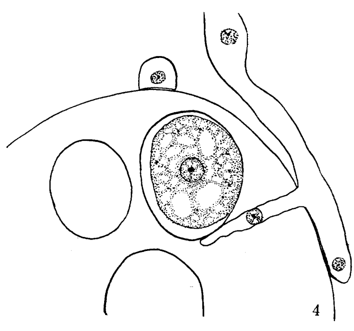

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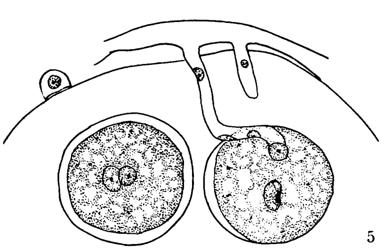

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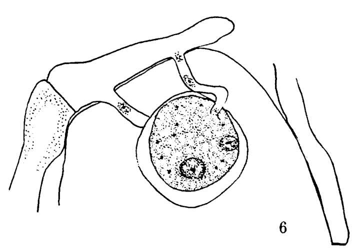

6

CYTOLOGICAL STUDIES ON THE SPORANGE DEVELOPMENT AND GAMETOGENESIS IN BREVILEGNIA DICLINA HARVEY

George Olds Cooper

Introduction

Primary interest has been directed to the sexuality of the Saprolegniaceae and for many years there has been considerable discussion as to whether or not fertilization does actually occur.

Pringsheim (1855, 1858, 1860), working with various members of the Saprolegniaceae, while he did not actually observe fertilization, believed that it took place. Zopf (1882, 1883) declared that Pringsheim did not have fertilization, but that what he saw were "spermamoeben" zoospores of a parasitic fungus. Cornu (1872) believed fertilization was present in *Achlya polyandra* Hild. and *Achlya racemosa* Hild. He demonstrated that the structures which Pringsheim considered antherids were the sporanges of parasites, probably of a Chytrid.

De Bary (1884) did not share Pringsheim's views and in his "Comparative Morphology and Biology" stated that while the antherid may approach the oogone and penetrate it and even continue on through and pass out the other side, it does not discharge its protoplasmic content.

Humphrey (1892) was the first investigator to fix, imbed, cut, and stain his material. He described the behavior of the nuclei within the oogones of *Achlya americana* Humphrey and *Achlya apiculata* de Bary. He stated that the nuclei did not divide, but repeatedly fused in pairs until each egg contained only one nucleus. He agreed with de Bary that the fertilization tube may enter the oogone and approach the egg, but that it does not discharge the male gamete–nucleus.

Hartog (1892, 1895), staining in toto, agreed with Humphrey that the nuclei in the oogone fused until each egg contained a single nucleus and that there were no mitotic divisions within the oogone. He, too, insisted that fertilization did not occur; antheridia approached the oogones, but there was no discharge of their protoplasmic contents.

Trow (1895) disagreed with Hartog as to the fusion of nuclei and as to whether there was an actual fertilization. He described nuclear divisions in the oogones and antherids of *Saprolegnia diocia* and observed where the fertilization tube had discharged the male gamete–nucleus into the egg. From 1896 to 1899 there was a bitter controversy between Hartog and Trow as to the behavior of the nuclei and as to the occurrence of fertilization, but they came to no agreement.

Davis (1904) worked with *Saprolegnia mixta* which he believed to be apogamous. He described one division within the oogonium. The chromosome number was four and there were no centrosomes present. He found in the early formation of the egg a structure which he called a coenocentrum, from which delicate fibrillae radiated. The coenocentra were formed de novo, one for each spore origin. Its function, he believed, was concerned with the "balling" or rounding up of the egg and that it exerted a chemotactic influence over nuclei that were near it. These nuclei were nourished by the coenocentrum as they increased in size. Generally one nucleus persisted in the egg, but occasionally two or three and in such instances the eggs were bi- or tri-nucleate.

Trow (1904) worked on *Achlya polyandra* Hildebrand and observed a fertilization tube in direct open communication with a young egg. In *Achlya debaryana* Humphey the nuclei undergo two divisions within the oogone, the second of which Trow believed to be in the nature of a reduction division. Fertilization occurred in this species.

Claussen (1908) with *Saprolegnia monoica* (Prings.), Mücke (1900) with *Achlya polyandra* de Bary and Kasanowsky (1911), with *Aphanomyces laevia* de Bary have observed fertilization to be present.

Carlson (1925) with *Achyla racemosa* Hildebrand described the divisions of the nuclei within the oogone. She believed that the central vacuole in the young oogone was the active agent in the cutting out of the egg initials and not the coenocentrum described by Davis (1905). She observed a body that might be termed a coenocentrum, but observed it only a few times. As complete evidence for fertilization she described the discharge of the male gamete–nucleus into the egg, the migration of the male gamete–nucleus to the female gamete nucleus, and finally the union of the two.

Couch (1925) with *Leptolegnia caudata* de Bary observed fertilization in this species. The penetration path left in the cytoplasm by the male gamete nucleus is of interest as it has not been previously recorded.

Materials and Methods

The material was secured from Mr. J. V. Harvey who isolated it from soil gathered in the vicinity of Madison, Wisconsin. Cultures were grown on boiled hemp seed in distilled water. Single sport cultures were made and within three days to a week oogonia became abundant. The material was identified as *Brevilegnia diclina* Harvey. It was fixed in formol-acetic-alcohol. The material was imbedded by the paraffin method and sectioned to a thickness of 5 microns. Haidenhain's iron–alum haemotoxylin stain with a counter stain of light green gave the best results.

Development of the Sporanges

The mycelium of *Brevilegnia declina* Harvey is dense and rather opaque, the hyphae are straight and sparingly branched. The sporanges appear within a day in cultures growing on boiled hemp seed, at nearly all the hyphal tips, but also arise from the same point in sympodial groups.

The writer, while cooperating with Mr. Harvey in the examination of material, observed two characteristic types of primary sporanges, one long and slender, with the spores arranged in a single row except for a small cluster of spores at the tip of the sporange, the other ovate to long club-shaped as in *Thraustotheca clavata* (de Bary) Humphrey. Secondary sporanges appear in dense sympodial clusters terminally or frequently below the primary sporanges. As in Thraustotheca (Weston, 1918), typical sporanges are broadly clavate and lack papillae of dehiscence. The sporanges of Brevilegnia develop on the dimunition of the food supply, agreeing in this respect with the general law established by Klebs (1899).

Sporange formation begins with the gradual streaming of the protoplasm to the hyphal tip which, as a result, begins to swell slowly. In time the accumulation of protoplasm fills the sporange initial and a cross wall is then formed across the base of the sporange. The contents now begin to differentiate into spores. In the sporange having the spores arranged in a single row in section view, there appears at the tip of the sporange a vacuole which by enlargement and furrowing cuts out the spore initials (fig. 2). The formation of the spore initials in the remaining part of the sporange is caused probably by a furrowing of vacuolar and plasma membranes.

In longitudinal sections of the larger club-shaped type of sporange, the vacuole first appears near the tip and continues on down through the center of the sporange (fig. 5). Here, as in the other type of sporange, the enlargement and furrowing of the vacuole cuts out the polygonal spore initials. In both types of sporanges the spore initials are at first distinct and then for a space become slightly indistinct, due probably to the readjusting of the spore initials and the movement of the liquid in the vacuole. The spore initials, now granular in appearance, form a wall about themselves and become more and more distinct. Weston, in Thraustotheca, states that the sporangiospores imbibe water and swell, but in Brevilegnia, on the contrary, the spores throw off water and the cytoplasm appears to contract. This is now evidently an encysted state. The completed spores occupy the same position as did the spore initials.

In this form, as in Thraustotheca, it is to be noted that there is no evidence of an intersporal substance, a condition in agreement with the observations of Rothert (1890) and Humphrey (1893) for other Saprolegniaceae.

It is interesting to note that in the formation of the spore initials the vacuole does not cut out uninucleate masses of protoplasm as has been observed in all other of the Saprolegniaceae (fig. 2). In section view the sporangiospores (aplanospores) show a multinucleate condition. The nuclei are quite distinct, each with a definite nuclear membrane and a conspicuous irregularly shaped nucleole. A fine granular network appears to run from the nucleole to chromatin material at the periphery of the nucleus. The nuclei vary slightly in size; the smaller ones, however, show no indications of degeneration. Weston uses the term sporangiospore to indicate a non-motile spore, thereby distinguishing it from the term zoospore. Since the sporangiospores are monoplanetic the term sporangiospore is not quite applicable in this case. In Brevilegnia the writer suggests the term aplanospore as the spores are non-motile at all times.

The method of the liberation of the spores agrees partially with that of Thraustotheca which Weston believes differs from that of any other genus in the Saprolegniaceae. As has been mentioned, the papillae of dehiscence which are present in most members of the family are lacking in Brevilegnia, and the aplanospores escape by the disintegration of the sporange walls. In a cross section of the larger club-shaped type of sporange, the spores are arranged about the central vacuole. There is no rupture of the wall by the swollen sporangiospore as in Thraustotheca, but rather a disintegration of the wall here and there due in all probability to either chemical or enzyme action (fig. 6). The aplanospores are shed either singly or more commonly in small groups of two or three, often with portions of the sporange wall adhering to them. Upon leaving the sporange they round up, clinging together. This is in accordance with Weston, who observes a distinct adhesion and mutual attraction among the spores. Aplanospores remain sticking to any hyphae with which they may come in contact. They now have definite membranes or walls with the protoplasm slightly contracted (fig. 7). The cytoplasm is finely granular with small vacuoles, nuclei many, 7–15 having observed in some instances.

The aplanospores float about in the water, showing absolutely no signs of motility. Germinating spores or zoospores were not observed. Harvey believes that the aplanospores undergo a period of rest before germination, omitting the zoospore stage, and produce a germ tube directly. Couch, however, succeeded in producing zoospores from aplanospores by placing some of them in distilled water to a pH of about 4, or filtering them through animal charcoal. Gemmae were not observed by Harvey or the writer.

Development of the Oogones

The oogones arise singly and apically from hyphae on short lateral branches of the mycelium. In the formation of the oogone there is a streaming of the protoplasm into the hyphal tip, forming in it a marked swelling. The streaming continues until the swelling has caused the hyphal tip to become almost spherical. A cross wall is now laid down at the base of this swelling and the oogone is thus formed (figs. 8–10). The cytoplasm at this stage is multinucleate; conspicuous vacuoles are present surrounded by cytoplasm containing granules (mitochondria) of varying size and shape. A conspicuous, dark-staining body resembling a nucleolus is observed in each of the nuclei. This body seems to be identical with that described by Hartog as a chromatin body, by Trow as a combination of a chromosome and a nucleolus, by Davis, Claussen, Mücke, and Carlson as a nucleolus.

A vacuole remains in the center of the oogone after the formation of the cross wall at the base. Many of the nuclei migrate to the periphery of the oogone, where they very soon show indications of degeneration. The remaining nuclei appear to enlarge slightly and to stand out clearly.

These nuclei appear to undergo one mitotic division only. That there is only one division occurring within the oogone (figs. 8, 9) agrees with the results found by Davis, Claussen, Mücke, Kasanowsky, and Carlson in regard to closely related species. Trow (1904) describes the occurrence of two divisions in the oogone, the second of which he believes to be a reduction division. Contrary to other workers who state that the nuclei divide simultaneously, the writer observed nuclei in resting stage and in various stages of division within a single oogone (figs. 8, 9). The chromatin-linin network becomes very massed in the prophase and with the nucleole still quite prominent it is very difficult to make accurate determinations of chromosome behavior.

The metaphase has been observed frequently (figs. 8–10). The chromosomes are massed together at the equator of an intranuclear spindle. Few spindle fibers are present. Asters with only the suggestion of rays could be seen (fig. 9). In the anaphase the chromosome masses are to be noted. The chromosomes can be seen at this stage but they are so crowded it is impossible to make accurate counts. The writer believes the number to be comparatively few (4–8) and in no instance as many as 14–16, mentioned by Claussen. The telophase has been observed in a few instances and only a massing of cytoplasm at the poles could be made out.

After the nuclear divisions, the oogone evidently throws off water because there is a marked contraction of the cytoplasm from the wall. The vacuole in the center disappears and the cytoplasm becomes uniform throughout. This aggregated mass of cytoplasm becomes now the single egg which is constant in this species.

Formation of the Eggs

Davis, working with an oogone containing several eggs, found a body which he terms a coenocentrum and which he thinks is instrumental in the rounding up of the eggs. The cytoplasm in the oogone remains adherent to the wall and the central vacuole, by enlarging and furrowing, cuts out masses of cytoplasm, each with its respective nucleus. Beside each nucleus a body appears, the coenocentrum, which he thinks aids in the rounding up or "balling" of the cytoplasm. This body acts as a dynamic center which draws the cytoplasm to it and rounds it up into a spheroid mass. Miss Carlson and Claussen observed a body which they said might be termed a coenocentrum but observed it only a few times. In Brevilegnia, on the contrary, with the contraction of the cytoplasm and the disappearance of the central vacuole, there is no indication of a coenocentrum (fig. 12). The loss of water from the oogone causes the rounding up of the cytoplasm.

The nuclei that have recently undergone division are fairly evenly distributed throughout the cytoplasm, but there is a tendency for them to arrange themselves at the periphery of the egg (fig. 12). All the nuclei except one shortly begin to show signs of degeneration. The remaining nucleus enlarges slightly and is now the female gamete-nucleus. The nucleus becomes slightly flattened and the chromatin-linin network appears to radiate from the nucleole to the nuclear membrane where the chromatin appears to be more aggregated. The vacuoles in the egg are fairly uniform in shape, those near the center being somewhat larger than those at the periphery. The degenerated nuclei persist until after fertilization. The mature egg is found generally at one side of the oogone just prior to fertilization.

Behavior of the Antherids

During the formation of the egg in the oogone, antherids have been approaching the oogone from the same hyphae or from neighboring hyphae. Antherids have been observed to attach themselves to the oogones after the formation of the egg, but more frequently they are present at the stage of egg formation. The development of the male gametes within the antherid was not observed in Brevilegnia, but on the basis of the observation of other workers it is thought comparable with the changes taking place within the oogone during the formation of the egg. The antherid upon coming in contact with the oogone may indent the oogone. The rupture of the wall and discharge of its contents into the oogone was not observed. The presence of a fertilization tube has not been observed in this form. The antherid which adheres to the wall of the oogone at the spot where the egg touches the wall appears to be the functional antherid. There is evidently a dissolution of the wall of the oogone at the point of contact of the antherid and the egg. Apparently one of the gamete nuclei migrates into the egg. Several nuclei are often present within the antherid and the terminal nucleus appears slightly larger than the others and is probably the nucleus that functions as the male gamete-nucleus (fig. 15). Upon the discharge of the male gamete-nucleus into the egg, the other nuclei in the antherid show signs of degeneration.

After the formation of the egg, the wall of the oogone is quite irregular with several papillae Shortly before fertilization the oogone wall stretches slightly and the papillae disappear. Previous workers have observed that the wall of the oogone in a number of species varies in thickness. The oogone wall, in section view, appears to be made up of many circular thickened plates at the intersection of which are thin-walled regions. In section view, this gave the appearance of thickened areas separated by thin membranes. It has been thought for a long time that the antherid paused at a thin area or that the fertilization tube penetrated the thinner areas only, due probably to some chemotactic stimulus. Couch, in his studies with the water molds, has observed that the fertilization tubes penetrated the thickened areas as well as the thinner ones, and so believes that there is no ground for the assumption that the fertilization tubes penetrate the thinner areas only.

FERTILIZATION

After the male gamete nucleus has been discharged into the egg it migrates toward the female gamete nucleus. The male gamete nucleus can be readily recognized within the egg (fig. 17). It is almost spherical and slightly smaller than the female gamete nucleus. A nucleolus can be seen within each of the nuclei. It was not uncommon to find the female gamete nucleus at a distance from the center of the egg. In many preparations, while it may not be characteristic for the species, the writer has observed that the male gamete nucleus was invariably discharged into the egg (fig. 17) at the side farthest away from the female gamete nucleus.

Several stages have been observed of the male gamete nucleus on its way to the female gamete nucleus. The male nuclus leaves in its wake a path of dense cytoplasm, which Couch calls the "penetration path" (figs. 17, 18, 19). Couch describes such a path in *Leptolegnia caudata* de Bary. The male gamete nucleus comes to lie next to the female gamete nucleus, one slightly overlapping the other. Upon the union of the gamete nuclei the egg becomes a zygote. A wall now appears about the zygote. The cytoplasm becomes quite vacuolate. Several large vacuoles are found in the vicinity of the zygote nucleus, with many smaller ones at the periphery. Shortly before fertilization a small opaque body appears in the egg and after fertilization it enlarges rapidly (figs. 23, 24). Occasionally there may be more than one. These bodies are easily recognized as oil bodies because of their definite outline and because of their staining reaction. Faint fibrillar lines are present over their surfaces. An oil body may enlarge until in some instances it is about two-thirds the size of the zygote.

The zygote evidently undergoes a period of rest before germination. Germinating zygotes were not observed. In several zygotes a multinucleate condition has been observed with resting nuclei (fig. 25), but a most careful study of a very large number of preparations has given no evidence as to when such division begins. No one has as yet given a complete story of the processes which intervene between fertilization and the germination of the zygote in any of the Saprolegniaceae.

Summary

In Brevilegnia the development of the sporanges agrees with other members of the family.

The sporangiospores are multinucleate, a fact which has been observed in only one other genus of the Saprolegniaceae.

The method of spore liberation is by the dissolution of the sporange wall and not by the rupture of the wall, by the contraction and rupture of the wall by the enlarging zoospores, nor by the assistance of an intersporal substance as has been noted by earlier observers.

The sporangiospores are non-ciliate at all times. They float about for a time, settle into substrate and germinate directly into hyphae.

Prior to the liberation of the sporangiospores from the sporange the spores appear to encyst as there is a marked contraction of the cytoplasm from the wall of the spore.

A single division of the nuclei takes place in the young oogone which is in agreement with the results of recent workers in other members of the family.

The oogone contains a single egg only, which is found generally at one side of the oogone.

The antherids approach the oogone during the formation of the egg. After attaching themselves to the oogone, the antherid nearest the egg is the functional antherid. The antherid possesses no fertilization tube. The separating walls dissolve and the male gamete nucleus passes directly from the antherid into the egg and migrates to the female gamete nucleus leaving in its wake a penetration path.

The gamete nuclei fuse and the egg becomes the zygote.

No nuclear divisions were observed in the zygotes, but several zygotes were observed in a multinucleate stage.

The writer wishes to express his appreciation to Prof. E. M. Gilbert for his advice and encouragement during this investigation.

Explanation of Plates

All drawings were made with the aid of a camera lucida at table level with a Leitz No. 4 ocular and a 1/16 oil immersion, making a magnification of 1750.

Plate 3

FIG. 1. Tip of young multinucleate sporange with the first appearance of the central vacuole.

FIG. 2. Sporange with the spores in a row. Aplanospores being cut out by the central vacuole and by the furrowing from the side of the sporange. Aplanospore initials present.

FIGS. 3, 4. Cross section of the club-shaped type of sporange with the aplanospores arranged about the central vacuole. Cytoplasm has contracted slightly, evidently an encysted condition.

FIG. 5. Longitudinal section of the club-shaped type of sporange showing the position of the central vacuole.

FIG. 6. Aplanospores of the sporange bearing the spores in a single row, showing the irregular manner of the disintegration of the sporange wall; the spores remaining clustered together.

FIG. 7. Club-shaped type of sporange at maturity, anterior portion of sporange disintegrated and the aplanospores about to be liberated.

Plate 4

FIGS. 8, 9. Longitudinal sections of an oogone prior to its assuming typical spherical shape. Nuclei in various stages of division; some nuclei in the resting stage.

FIGS. 10, 11. Longitudinal sections of young oogones which have rounded up with the nuclei in various stages of division.

FIG. 12. Multinucleate egg after the division of the nuclei. The cytoplasm contracted, the vacuole has disappeared.

FIGS. 13, 14. Uninucleate eggs with the supernumerary nuclei disintegrating.

FIG. 15. Antherids from adjacent hyphae attached to oogone.

FIG. 16. Antherid from same hypha in contact with oogone wall opposite egg, showing position assumed at time of fertilization.

PLATE 5

FIG. 17. Egg with the male gamete nucleus approaching the female gamete nucleus, leaving in its wake a penetration path.

FIG. 18. Egg with the gamete nuclei lying in contact. The penetration path is still in evidence. Antherid attached to oogone wall.

FIG. 19. Egg with gamete nuclei about to fuse. Penetration path still present.

FIGS. 20, 21, 22. Zygotes with the gamete nuclei about to fuse.

FIG. 23. An abnormal zygote in which the gamete nuclei have not fused. The presence of the oil bodies indicates that some time has elapsed since the male gamete nucleus entered the egg.

FIG. 24. Fully matured zygote, with fusion nucleus and well developed oil bodies.

FIG. 25. Zygote in a multinucleate stage prior to germination. Large oil body present.

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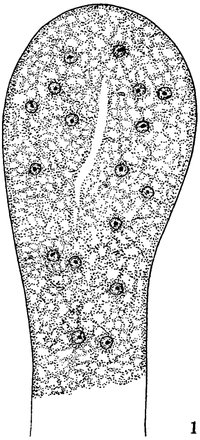
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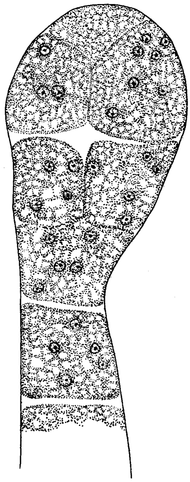
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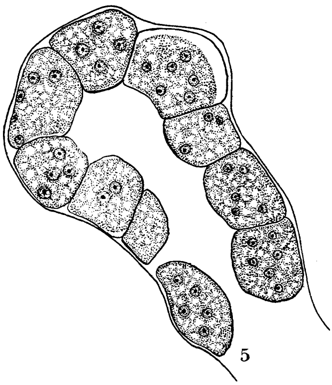
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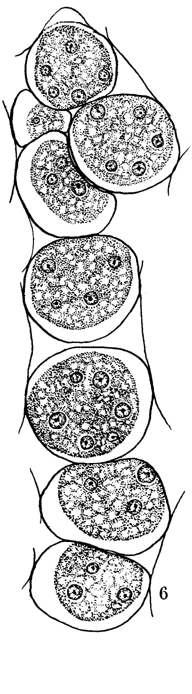
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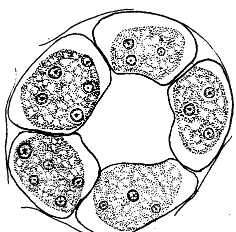
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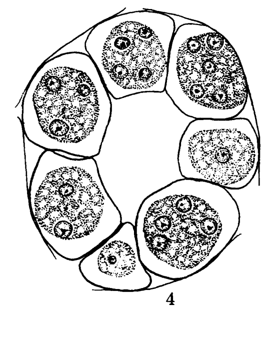
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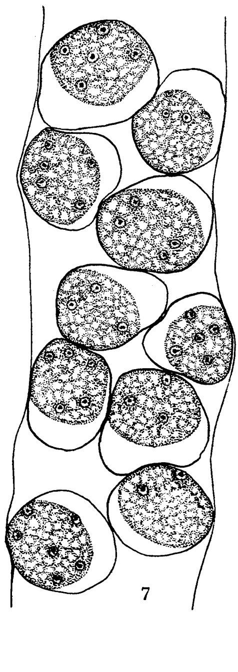
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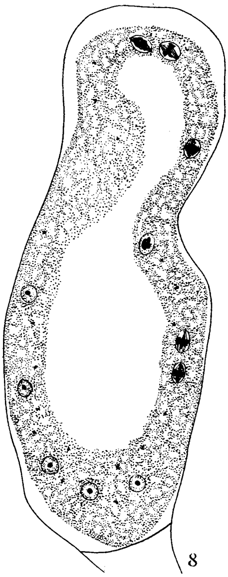
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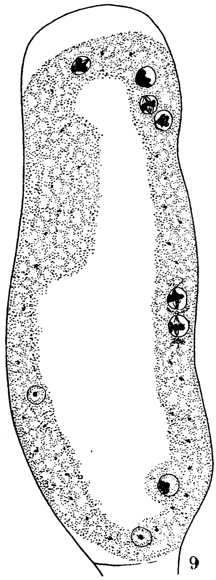
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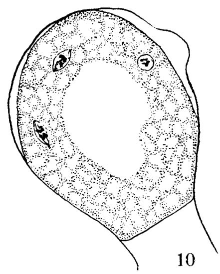
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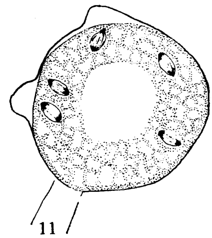
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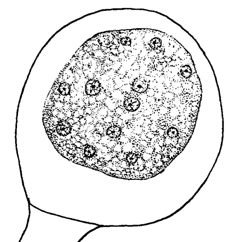
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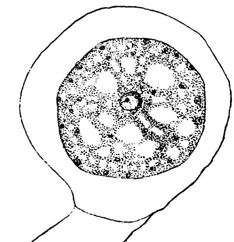
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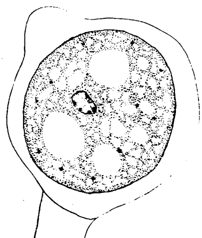
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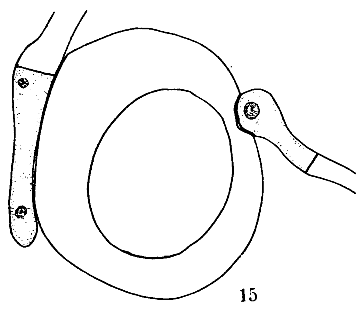
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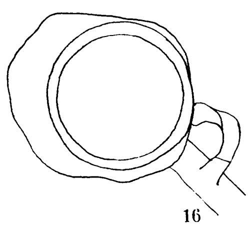
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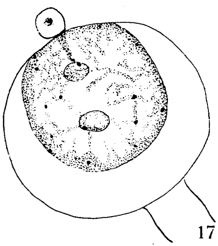

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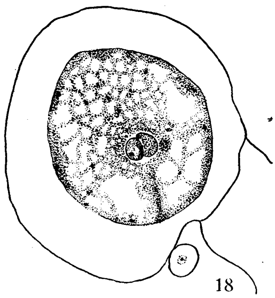

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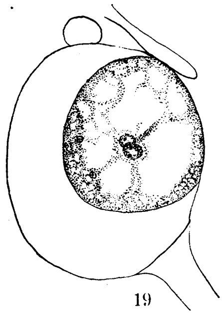

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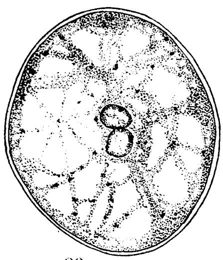

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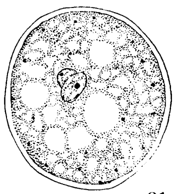

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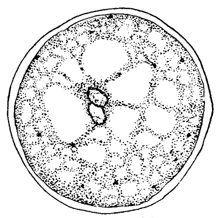

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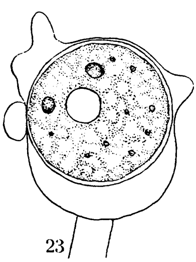

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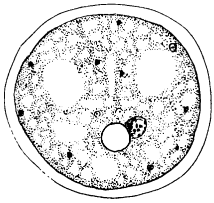

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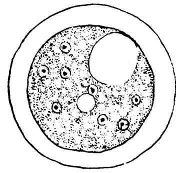

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THE CYTOLOGY AND MORPHOLOGY OF SORDARIA FIMICOLA CES. AND DE NOT

ADDIE EMMA PIEHL

INTRODUCTION

Recent cultural experiments dealing with the homothallism and heterothallism of fungi relating to the Sordarias has made it worth while to study the origin and nature of the structures initiating the formation of fruiting bodies in these forms.

Special attention has therefore been given to the growing of Sordarias in pure cultures so that the presence or absence of sex organs could be noted, as well as the nature and function of such organs during their development. Gross morphology was noted, but the nuclear phenomena, especially as to the behavior of the nuclei during the early stages in formation of the perithecium, has been given special consideration. As a preliminary to this study, a careful review has been made of the accumulated data, both cytological and morphological, of previous workers on the Ascomycetes.

HISTORICAL REVIEW

Pyronema confluens

The development and nature of the sex organs in *Pyronema confluens* have interested several investigators. The first descriptions were supplied by De Bary (1863), by the Tulasne brothers (1865, 1866), by Van Tieghem (1884), and by Kihlman (1885). These early investigators observed the elongated antheridium, the globular oogonium, the trichogyne, and the ascogenous hyphae characteristic of Pyronema. More detailed work of a cytological nature was necessary, however, before the history of *Pyronema confluens* could be considered complete. This led to the investigations of Harper (1900), followed by Dangeard (1903, 1907), and by Claussen (1912).

As a result of Harper's observations on *Pyronema confluens,* there has been obtained a detailed life history, a review of which follows. The vegetative mycelium is multinuclear, from six to twelve nuclei appearing in each cell. Although the mycelium is sparse and loose, the reproductive organs are abundant and produce ascocarps which, when mature, are seen crowded together.

The first appearance of sex organs may be noted when certain thick hyphae tend to stand at right angles to the substratum. These hyphae, from the same or different mycelia, may be seen grouped in pairs. One of the two branches becomes swollen and differentiates into an upper spherical cell, the oogonium, and a lower portion, the stalk, composed of a few cells; the other branch has an upper cell cut off which remains slender and is called the antheridium, with a lower portion forming the stalk cells. Very early in the formation of these sex organs, the trichogyne appears as a slight elevation at the "apex" of the oogonium. This trichogyne elongates, becomes multinucleate, and is separated from the oogonium by a wall.

The mature oogonium is a spherical or flask-shaped cell filled with dense cytoplasm and containing many nuclei larger than those of the vegetative cells. The nuclei of the antheridium are almost as large as those of the oogonium but the cytoplasm is less dense, due perhaps to the lack of reserve materials.

Before fertilization, hyphae from the ascogonial and stalk cells and from surrounding cells begin to grow up and later envelop the sex organs.

The trichogyne and the antheridium grow towards each other, the tip of the trichogyne finally coming in contact with the apex or side of the male organ. When fertilization is about to take place, there is a single receptive spot at the end of the trichogyne free from nuclei and made up of dense, finely granular cytoplasm. At the point of contact of the antheridium and trichogyne, a pore is formed by dissolution of the cell walls. During this process, the nuclei of the trichogyne degenerate and when they are completely disorganized, the nuclei of the antheridium migrate through the pore and into the trichogyne, in which the contents have degenerated still further so that the cytoplasm and nuclei together form a densely staining mass. The male nuclei continue to pass into the trichogyne which often appears filled and slightly swollen as a result. The wall at the base of the trichogyne now breaks down. This allows an opening for the male nuclei to enter the oogonium.

The greater part of the cytoplasm remains in the antheridium and trichogyne and does not enter the oogonium. After migration of the male nuclei through the trichogyne and into the oogonium, a new wall appears at the base of the trichogyne so that the oogonium is again a single cell. The male nuclei pair with the female nuclei and these paired nuclei then fuse within the oogonium. During this time slight protuberances make their appearance in the walls of the oogonium which is called an ascogonium after fertilization takes place. These projections elongate and are young ascogenous hyphae into which the fusion nuclei soon pass. These hyphae lengthen in a crooked fashion, become septate, and grow among the vegetative branches which have arisen from the stalk cells of the oogonium. The vegetative branches grow faster than the ascogenous hyphae and continue to grow upward, their extremities becoming paraphyses. The ascogenous hyphae also grow in a vertical direction and appear among the paraphyses, but their upward growth soon stops and they then grow horizontally, branching repeatedly, forming a network at the base of the hymenium.

The tips of the ascogenous hyphae which extend upward among the paraphyses, become curved. They contain, at first, two nuclei which divide simultaneously so that four nuclei are found in the curved portion, and these nuclei are arranged in such a way that the two nuclei from separate spindles lie together in the "crook" of the branch, one nucleus in the tip and one below the curve. Cell walls then appear, cutting off the tip with one nucleus, the bent upper part of the branch with two nuclei. It is from this binucleate cell that the young ascus arises as an apical projection into which the two nuclei pass and then fuse. This fusion-nucleus or primary nucleus, as it is usually called, divides to produce two, then four, and finally eight nuclei arranged throughout the entire length of the now fully elongated ascus.

Each nucleus has a beak and to this are attached the aster rays which still remain. These fibers grow back around the nucleus until they meet and a membrane is formed around each nucleus. Thus the ascospores are cut out by a process called a "free cell-formation." Later a wall forms around each uninucleate spore.

Harper, therefore, finds that the nuclei in the antheridium pass through the trichogyne and into the oogonium where they pair with the female nuclei and fuse. These fusion-nuclei then pass into the ascogenous hyphae. Harper thus finds two fusions in *Pyronema confluens,* one in the oogonium and one in the ascus when the two nuclei from the penultimate cell unite to form the primary nucleus of the young ascus. Then chromosomes were counted by Harper in the divisions of the nuclei in the ascogenous hyphae and in the divisions of the primary nucleus in the ascus but whether this number represents a double number resulting from the fusion in the oogonium or whether reduction division has already taken place, Harper was unable to decide.

Dangeard (1903–1904) disagrees with these conclusions given by Harper. The sex organs, he believes, are not functional. The wall between the oogonium and the trichogyne does not disappear so that the migration of male nuclei beyond the trichogyne can not take place. Ascogenous hyphae arise from the functionless sex organs and the asci possess characteristics of a sex organ in which the nuclei fuse as gametes. This fusion-nucleus then divides by heterotypic division followed by two homoeotypic divisions. There is, therefore, according to Dangeard, only one nuclear fusion and that in the young ascus.

The theory of a single nuclear fusion is also advanced by Claussen (1912). His conclusions, concerning the development and function of sex organs and the migration of male nuclei through the trichogyne and into the oogonium, agree with those of Harper. But, according to Claussen's investigations, the male nuclei pair with the female nuclei but there is no fusion in the oogonium. These paired nuclei pass into the ascogenous hyphae and then fuse in the young ascus as described by Harper and Dangeard. A single division then follows with two homoeotypic divisions in the ascus. Claussen has counted twelve chromosomes in these divisions.

Brown (1915) finds no union of antheridium with trichogyne, no fusion of nuclei in the ascogonium and none in the ascogenous hyphae. He agrees with Claussen and Dangeard in the single fusion thory, that fusion taking place in the young ascus.

Phyllactinia corylea

In *Phyllactinia corylea,* Harper (1905) finds a small coil composed of the functional oogonium and antheridium which appear at about the same time as lateral branches from separate hyphae but from the same mycelium. The oogonium is cut off from its hypha by a cross wall so that a large upper cell and a small lower cell results. The upper cell enlarges to form the oogonium and contains a single nucleus, the lower cell divides to form the stalk cells of the oogonium. The antheridium is formed in a similar manner but remains slender and erect and contains one nucleus. The oogonium grows more rapidly and twists around the short, erect antheridium. The walls separating the two sex organs, at the point of contact, break down and a pore is thereby produced for the passage of the male nucleus into the oogonium. A part or all of the cytoplasm remains in the antheridium. Fusion of the two nuclei then occurs in the oogonium. The pore between the two sex organs closes and the antheridial cell degenerates. While fertilization is going on, protective branches grow up from the stalk cells of both sexual branches and begin the formation of the perithecial envelope.

The oogonium, after fertilization, is called the ascogonium. It enlarges and a division of the fusion-nucleus takes place. This binucleate cell remains in this condiiton until the ascogonium is completely enclosed by the enveloping hyphae. Then the two nuclei divide and just how many divisions occur before cell walls appear, Harper was unable to observe. However, from three to five cells in a row appear in the ascogonium, the end cell with one nucleus, the others with one or two nuclei. Ascogenous hyphae arise as lateral branches from the ascogonium cells and whether they come from one cell or from several of the upper cells is unknown. It is certain that some arise from the penultimate cell. The ascogenous hyphae develop considerably before they become septate; then cells with two nuclei and with one nucleus result. From the binucleate cells, the asci are formed as lateral outgrowths probably in the same manner as in Pyronema.

Each young ascus has two nuclei. The ascogenous cells which formed the asci contained two nuclei, but these nuclei are not necessarily daughter nuclei of the same nucleus. As the asci elongate, the two nuclei in each ascus fuse, forming the primary ascus-nucleus which moves to the lower end of the ascus. By this time the asci have become long, narrow structures with short stalks at the base. The primary nucleus undergoes three nuclear divisions so that eight nuclei are formed. By free cell-formation, eight spores are cut out.

The perithecium at this time has a three-layered wall; the innermost layer several cells in thickness, thin-walled, and probably supplying food for the developing asci. Outside of this layer is a strengthening and protecting zone of cells with walls which appear lignified. The outermost layer of the perithecium consists of thin-walled cells from which characteristic appendages arise as stiff, pointed hairs with swollen bases.

Ascobolus magnificus

Dodge (1920) found that cultures containing two strains of mycelia were necessary for the production of ascocarps. In such cultures four to six days old, he found paired branches. These club-shaped branches elongate. One of them usually grows faster than the other, coils about this shorter branch, and is called the ascogonium; the shorter structure remains a two or three-celled antheridium. Very often both branches arise a short distance apart. In this case, one remains an erect, short antheridium, the other elongates into an ascogonium and forms a trichogyne which grows to and becomes coiled about the antheridium.

Dodge was able to prove the presence of an antheridium in any normal case by separating this same structure from the trichogyne coil before fusion had occurred and if hyphal branches had not grown out from the stalk of the oogonium to envelop the male organ.

In normal development, the ascogonium enlarges and often ascogenous hyphae grow out before sterile hyphae begin to form the fruiting body.

Since two strains of mycelia are necessary for the production of fruiting bodies, there is good indication that sex has not been lost or reduced in at least this species of Ascobolus.

By germinating ascospores of *Ascobolus magnificus,* Dodge obtained papulospores—defined by him as a spore "in which one or two large storage cells are surrounded by a covering of hyphae which develop from blister-like outgrowths of the storage cell." He transferred mycelia of the single papulospore strains to different kinds of media but obtained no ascospores of Ascobolus. Hotson, at Dodge's request, studied papulospores from cultures sent by the latter and concluded that they were not the asexual stage of *Ascobolus magnificus.* He was unable to obtain ascospores from the cultures.

E. S. Schultz also made single spore cultures of this papulaspora for Dodge, but was unable to obtain ascocarps.

Recently Dodge proved that papulospora is not a case of parasitism on Ascobolus as he once thought, but is an example of what has been described as self-penetration or self-parasitism. Internal hyphae running in and out of larger hyphae were found with papulospores arising from branches growing out of these internal hyphae.

As already noted, ascocarps could not be obtained from single spore cultures of papulospores and there is no record of producing ascocarps from single ascospore cultures of *A. magnificus.* Two strains are thus necessary for sexual reproduction and the formation of ascocarps. Dodge planted single ascospore cultures in separate petri dishes and obtained mycelium and papulospores but no sex organ branches or ascocarps. Of the seven strains obtained he planted five of them as follows:

Strains	Results after 10 days
2 alone	Papulospores but no fruiting bodies
2 and 1	Ascocarps
2 and 3	Papulospores but no fruiting bodies
2 and 4	Ascocarps
2 and 5	Papulospores only
6 lost	
7 not used	

The results prove that strains 2, 3, and 5 when grown in the combinations given in the table are sterile; the same is true for strains 1, 4, and 7. Fertile cultures, however, are produced when any one of the first group is grown with the different strains in the second group.

Strains 2 and 4 were further tested. It was found that each is sterile when grown alone, but fertile when combined with the other. Strains 2 and 1, although sterile when grown alone, produced ascocarps when grown together. But strains 4 and 4 grown together in one petri dish will show a zone between them free from hyphae. When opposite strains 2 and 4 are planted, there is no such zone between them and sex organs appear throughout the culture. Therefore, according to Dodge, each strain is self-sterile and in a single strain culture produces no sex organs. Sexual reproduction occurs only in cultures containing two strains properly chosen.

Venturia inaequalis

Frey (1924) has reported the presence of an ascogonium, a trichogyne, and antheridial branches which indicate sexual conditions in *Venturia inaequalis.* The coil usually consists of two branches which arise from the same filament. One branch functions as an ascogonium, the other is not an antheridium but may function as a nutritive organ. Sometimes a single branch may be found producing a coil. The coil increases in size, stains deeply, and sends out an elongated projection called the trichogyne. Early stages of the trichogyne and ascogonium are non-septate—the former seldom has a nucleus, while the latter is multinucleate. From the filaments near the ascogonium, the antheridial hyphae arise. Their apical cells are enlarged and some appear multinucleate, probably functioning as antherids because they come in contact with the trichogyne and seem to fuse with it. Just when, in the development of the coil, fertilization occurs, is not known, but since later stages show paired nuclei in cells of the ascogonium, it probably takes place during the non-septate stage.

After fertilization, the ascogonium becomes septate and contains seven or eight cells with paired nuclei, as already mentioned. These nuclei do not fuse in the ascogonium. Later there is an increase in number of cells in the ascogonium, some of which may contain as many as four nuclei. These cells branch extensively, are septate, and certain of these cells may become asci directly, other cells may again branch, and these branches then become septate and form asci. Frey does not consider these branches equivalent to the ascogenous hyphae described by Harper and Claussen.

The ascogenous cells contain two or four nuclei which enlarge and pair and these paired nuclei then fuse in the young ascus. The nuclei resulting from the division of this primary nucleus lie near the center of the ascus, but after the second division when the ascus has elongated, the nuclei pass to the periphery. After the third division the spores are cut out by the astral fibers as described by Harper. These spores are two-celled and uninucleate.

Killian (1915) reported a large trichogyne, a coiled ascogonium, and also a branched antheridium in *Venturia inaequalis*. Frey found a few lobes of the apical cells of antheridial branches and perhaps these lobes correspond to the branched antherids found by Killian. Killian suggests the possibility of a septate archicarp at the time of fusion of antherid and trichogyne because of pores found in cells of the ascogonium.

Polystigma rubrum

In *Polystigma rubrum,* Nienburg (1914) found a coil composed of an ascogonium, a trichogyne, and an antheridium. The ascogonium is an elongated cell with one nucleus; the trichogyne is multinucleate, does not function as a sex organ but perhaps has a nutritive value; the antheridium is an elongated cell with many nuclei. The antheridium applies itself to the ascogonium and the walls at the point of contact between the two cells break down. The male nuclei then pass from the antheridium into the ascogonium where one male nucleus enlarges to become the functional male nucleus—the remaining nuclei degenerate. No fusion of nuclei in the ascogonium was observed by Nienburg. From the ascogonium, ascogenous hyphae, the cells of which contain two nuclei, arise and whether this binucleate condition is due to a "constriction" division is an unsettled question. Development of the ascus could not be followed.

Nienburg did not observe a fusion of nuclei in the ascogonium or in the ascogenous hyphae and believes there is but a single fusion and that in the ascus.

Blackman and Welsford (1912) disagree with Nienburg. They claim that the ascogenous hyphae develop from vegetative cells, and that two nuclear fusions occur, one in the ascogenous hyphae and one in the ascus.

Podospora anserina

An organism more closely related to Sordaria than the forms described above, is *Podospora anserina*, a saprophyte commonly found on waste material. It was investigated for the purpose of determining spore formation because the number of spores produced in a few species of Podospora varies from four to sixteen or more.

Wolf (1912) made a study of *Podospora anserina* and found coils made up of two hyphae, but with no differentiation of sex organs. The nuclei are very small and for this reason, fusion of nuclei was not observed. Vegetative hyphae arise from the coil, envelop the coiled hyphae and develop into the pear-shaped perithecium.

Near the base of the perithecium, the asci develop in groups, several asci branching from a single hypha. The young ascus contains one large primary nucleus, much larger than those found in the vegetative mycelium where each cell is multinucleate. This primary nucleus undergoes divisions; only a few stages, however, were observed by Wolf. After heterotypic and homoeotypic divisions there is a short period of rest followed by an enlargement of the nuclei containing knots of chromatin which may represent chromosomes. After the third division a region of less dense protoplasm appears between pairs of the resulting eight nuclei. It was found that four spores are cut out of the ascus in *Podospora anserina,* but whether only one nucleus of each pair takes part in the process of spore delimitation or astral rays from the two concerned are effective was not determined. Since two nuclei are normally included within each of the four spores, no disintegration of the eight nuclei in the epiplasm takes place.

As the spores mature they increase in size, the nuclei migrate to the ends, the upper part enlarges and the lower half becomes the hyaline appendage. The nuclei increase in size and the colorless, young spores gradually change to green, then to dark brown. The appendage remains hyaline, becomes equal in length to the body of the spores, and often disappears in mature spores.

Sordaria fimicola Ces. and De Not

Sordaria fimicola Ces. and De Not. was first described by Roberge in 1849 and given the name of *Sphaeria fimicola* later in 1865. Cesalpini and De Notaris described the fungus more fully and gave it the name *Sordaria fimicola,* which name has been generally accepted. More recently, Griffiths and Seaver, in listing the Sordariaceae for the North American Flora, dropped the genus Sordaria as such and substituted Fimetaria and gave the new combination *Fimetaria fimicola* (Roberge) Griffiths and Seaver. As *Sordaria fimicola* has been so long accepted and is found as such in most literature, that name will be used in this paper.

Materials and Methods

Pure cultures of *Sordaria fimicola* Ces and De not. available for study, were easily isolated from refuse material and from impure cultures of Sordaria, and grown at room temperature on artificial media. It develops rapidly on potato agar, forming a great number of black, flask-shaped perithecia which stand upright above the medium. Spores from the most characteristic perithecia were then chosen and transferred to agar plates. Single spore cultures were then made from these cultures and pure strains of *Sordaria* *fimicola* were thus obtained. At different intervals, pieces of agar bearing mycelium and perithecia in various stages of development were cut out of the culture plates, fixed in Flemming's weak solution, imbedded in paraffin, and then cut into sections varying from 5 to 20 microns in thickness. A variety of stains were tried: Flemming's triple, Delafield's haematoxylin, Heidenhain's iron alum haematoxylin, and differential stains with the latter, such as licht gruen, fuchsin, iodine green, orange-G, erythrosin and Congo red. The best results were obtained with the 2 per cent iron alum haematoxylin and without a counterstain.

OBSERVATIONS AND DISCUSSION

The cytoplasm in the mycelium of *Sordaria fimicola* is highly vacuolate with strands of varying thickness extending throughout the cells. Close to the walls can be seen a thin, densely granular layer of cytoplasm. Imbedded in the cytoplasm are numerous mitochondria, either scattered singly, in aggregations, or often in pairs, probably as the result of recent division. The cells are multinucleate. With the exception of the nucleole which stains heavily, the content of the nucleus is not readily distinguishable. Cross walls with special thickenings as shown in figures 1, 4 and 5, are frequently present. A similar condition has been reported in Pyronema by Harper, and in various Basidiomycetes by several workers. These thickenings appear as darkly stained granules or as a mass of material centrally located on either side of the cross wall.

In several instances, branches arising at right angles to the mycelium and apparently from separate hyphae, grow toward each other and come in contact (figures 1–6). This is not a condition of ordinary anastomosing, but rather one of actual fusing of cell contents from the two closely applied hyphae as the result of a dissolution of the separating walls. This may occur at the tips or at various places in the lateral walls of the two branches (figures 4, 5, and 6). There is no differentiation of cytoplasmic content in the two branches and the nuclei in each cell are variable, but in several cases a difference in size can be noted in the two hyphae and in the mycelium from which the hyphae arise (figures 2, 3, 6). It is probable that the fusion of cell contents observed may be an initial step in coil formation, but intermediate stages, which might give conclusive results, are lacking. Miss Miller (1927), a research student in botany, made many single spore cultures of Sordaria and in every instance secured normal perithecia containing normal spores.

Repeated experiments with single spore cultures and with mycelium from single spore cultures gave the same results. She then made plantings of two spores and with portions of mycelium from different cultures to see what the effect would be, and in more than one hundred cultures of this type the perithecia appeared throughout the cultures indicating that all the strains with which she worked were homothallic.

In the majority of cases a typical coil arises where two hyphae come in contact (figures 7–20). In plate cultures four or five days old, upright branches which arise at right angles to the mycelium make their appearance. These branches originate from separate hyphae, grow toward each other and come in contact. One of them usually swells considerably, grows faster than the other, and initiates the formation of the coil. The two branches elongate and continue to coil about each other until a large coil is produced. Dodge (1920) finds that the coil in *Ascobolus magnificus* is differentiated into a definite male organ, the antheridium, which does not elongate but remains a short erect branch, and into a female organ, the oogonium which elongates, the end cell functioning as a trichogyne and coiling about the antheridium. Harper, in Pyronema, finds an elongated antheridium, a large, spherical oogonium with a trichogyne produced at the "apex"; the trichogyne and antheridium bring about fertilization. But in *Sordaria fimicola* no true oogonium, trichogyne or antheridium are distinguishable. Sordaria resembles *Podospora anserina* in this respect because both have little differentiation of sex organs. Due to the swelling of one branch in the initiation of the coil, there is a difference in size of the two sex organs as seen in figures 16–20, suggesting the presence of male and female elements.

The sex organs composing the coil are, therefore, elongated coiled branches with cross walls cutting off cells containing from one to seven nuclei. After fusion of certain of these cells an increased number of nuclei can be found in each cell of the coil proper. These fusion cells, probably representing simple or reduced sex organs, give rise to a variable number of hyphae which seemingly function as ascogenous hyphae in that the ultimate branches will give rise to asci. Whether they are true ascogenous hyphae such as are found in Pyronema and other forms or whether they more nearly resemble the ascogenous structures found in Venturia, it is impossible to state. The nature and arrangement of nuclei in these structures suggest that fusion has taken place, but the actual process of fusion has not been noted.

These hyphae branch repeatedly and as they develop they become more and more like the ascogenous hyphae described by others. The curved end of such a branch often contains four nuclei arranged in a row. Cross walls are then laid down in such a manner that the end cell contains a single nucleus, the second cell two nuclei, and the third cell again contains only a single nucleus (figures 22–25). The growth of the second (penultimate) cell causes the tip cell to bend backwards. In many instances it was found that all the cells except that at the tip contained two nuclei. In figures 23 and 24, the terminal cell can be seen to curve downward and the whole to give the appearance of the typical "shepherd's crook" commonly found at the ends of ascogenous hyphae in many Ascomycetes.

Most of these hyphae remain in large part within the coil, but occasionally (figures 20–25) the hyphae project beyond the coil and are then more characteristic of true "ascogenous hyphae."

Since the above was written, a paper by Arnold has appeared in which he gives the development of the perithecium and ascogenous hyphae in *Sporomia leporina* Niessl. The perithecium, which originates as a single enlarged cell of the vegetative mycelium, becomes a large rounded structure composed of several layers of cells, the innermost of which break down so that a cavity remains in the center. Extending into this cavity are the long hyphae which arise from the apex of the perithecium. Their enlarged tips, found near the base of the perithecium, give rise to ascogenous hyphae which bend upwards, become hooked, and finally cells are formed in the usual way as described in other forms.

Faull (1905) finds asci in *Sordaria fimicola* arising from the terminal cells as well as from penultimate cells of the ascogenous hyphae. In my material, the asci usually arise as lateral outgrowths from any of the cells which contain two nuclei. The young asci are short, swollen structures (figures 24 and 25) with dense cytoplasm and a large primary nucleus, the result of a fusion of the two nuclei which were present in the ascogenous cells which develop into young asci. The asci elongate and extend in a vertical direction beyond the coil which is located in the basal region of the now enlarging perithecium (figures 26, 27).

The primary nucleus lies at the center or above the center of the ascus. It is a well defined and easily distinguishable structure in contrast with the small indistinct nuclei of the vegetative cells. Within the nuclear membrane is one large nucleole and a network of chromatin material. This chromatin is not in strands as Harper (1905) finds in Phyllactinia, where the resting nucleus contains chromatin threads attached to a central body located against the nuclear membrane. These strands of Phyllactinia extend into the nucleus and correspond in number to the number of chromosomes counted later. In Sordaria, the primary nucleus in the resting condition has the chromatin in the form of a network characteristic of nuclei in higher plants (figures 28–30). The division of the primary nucleus has not been observed in any of the material studied, but results of division of the primary nucleus have been found. As division goes on, the asci elongate and finally eight nuclei are formed. Here again only the nucleole is visible in each nucleus (figures 31–34). Further elongation takes place as the asci mature. They become long, slender structures with the eight nuclei in a single row, extending throughout the entire length of the ascus. Eight spores are then cut out of the cytoplasm surrounding the nuclei, probably by "free cell-formation" as Harper observed in several Ascomycetes, although no intervening stages were observed from the time eight nuclei were visible until eight uninucleate spores were produced. No more than eight nuclei have been found in a single ascus but spores have been observed in which there are two nuclei, a condition which probably results from division of the nucleus within the spore. The spores are round when first formed, but become ellipsoid, acutely rounded at one end with a vacuolated cytoplasm. When mature, they have a thick wall surrounded by a gelatinous sheath (figure 35).

In addition to these main studies, attention has been given to the initiation of the perithecium. Vegetative hyphae arise in the neighborhood of the coil and envelop this structure. They begin to enclose the sex organs when the coil is still quite immature and by the time the "ascogenous hyphae" are formed, the vegetative hyphae have formed several layers of the perithecium. Sections of perithecia were observed in which a coil had been retarded in its development although the perithecial walls were fully formed and young asci were present. In such cases, the initiation of the perithecium probably takes place with the development of another coil from which the young asci originate. The inner layers of the fruiting body remain thin-walled, but towards the exterior the walls become impregnated with waxy substances, are thicker, and take the stain very readily.

At the time of ascus formation, hyphae resembling paraphyses can be seen in the interior of the perithecium and among the young asci. Later these hyphae disintegrate and when the asci are mature, no paraphyses or hyphae resembling them are present.

I wish to express my sincere appreciation of the helpful advice and criticism given by Dr. E. M. Gilbert during the progress of this work.

SUMMARY

Sordaria fimicola has recently been proved a homothallic species. In single spore cultures, perithecia appear in large numbers and in plate cultures inoculated with two strains, perithecia are abundant throughout the material, not limited to the region where the two different mycelia meet.

The sex organs are elongated, multicellular branches which coil about each other, forming large coils. They are undifferentiated except for a slight difference in size; no true antheridium, oogonium, or trichogyne are distinguishable.

"Ascogenous hyphae" arise from fusion-cells within the coil. Each hypha curves at the tip, forming a "crook" in which are found a uninucleate cell at the end, a binucleate penultimate cell and others with one or two nuclei.

Asci arise as lateral outgrowths from the binucleate cells, usually the penultimate, and the two nuclei fuse to form a primary nucleus. This nucleus undergoes three divisions and eight nuclei result which finally are cut out with a portion of the surrounding cytoplasm to form spores.

The uninucleate spores become binucleate as a result of the division of the nucleus present at the time the spores were formed.

As soon as the coil is well organized, hyphae cells increase in number and very soon completely enclose the coil and by a continued growth give rise to the various types of cells which characterize the perithecium of a Sordaria.

Explanation of Plates

Plate 6

All figures were drawn with an Abbe camera lucida, using a Leitz 4-ocular and a 1/16 oil immersion objective; magnification of 1850.

Photomicrographs were made with a Leitz 4-ocular, 1/16 oil immersion, magnification of 1300, with the exception of fig. 29, which was made with a 6 mm. objective, magnification of 500.

Figs. 1, 2. Two hyphae in contact. Cross walls with special thickenings are present, cells are multinucleate with only nucleoles visible. Fig. 2 shows hyphae of different size.

Figs. 3–6. As in Figs. 1 and 2. Dissolution of walls at place of contact and fusion of cell contents.

Figs. 7–20. Coil formation. No differentation of sex organs, merely a difference in size of the two hyphae can be noted.

Plate 7

Fig. 21. Tips of ascogenous hyphae showing multinucleate condition.

Figs. 22–25. Septate ascogenous hyphae. Fig. 23 shows the binucleate penultimate cell which usually gives rise to asci. Figs. 24, 25 show young asci developing as lateral outgrowths.

Figs. 26, 27. Elongating asci with a primary nucleus visible in some.

FIGS. 28–30. Portions of asci showing large primary nucleus with distinct nucleole and a network of chromatin material.

FIG. 31. Portions of ascus after first division of primary nucleus.

FIG. 32. Ascus with two nuclei.

FIGS. 33, 34. Asci with 8 nuclei, only 6 visible.

FIG. 35. At left, a spore from an ascus containing 8 spores. At right, a spore from an ascus with 4 spores.

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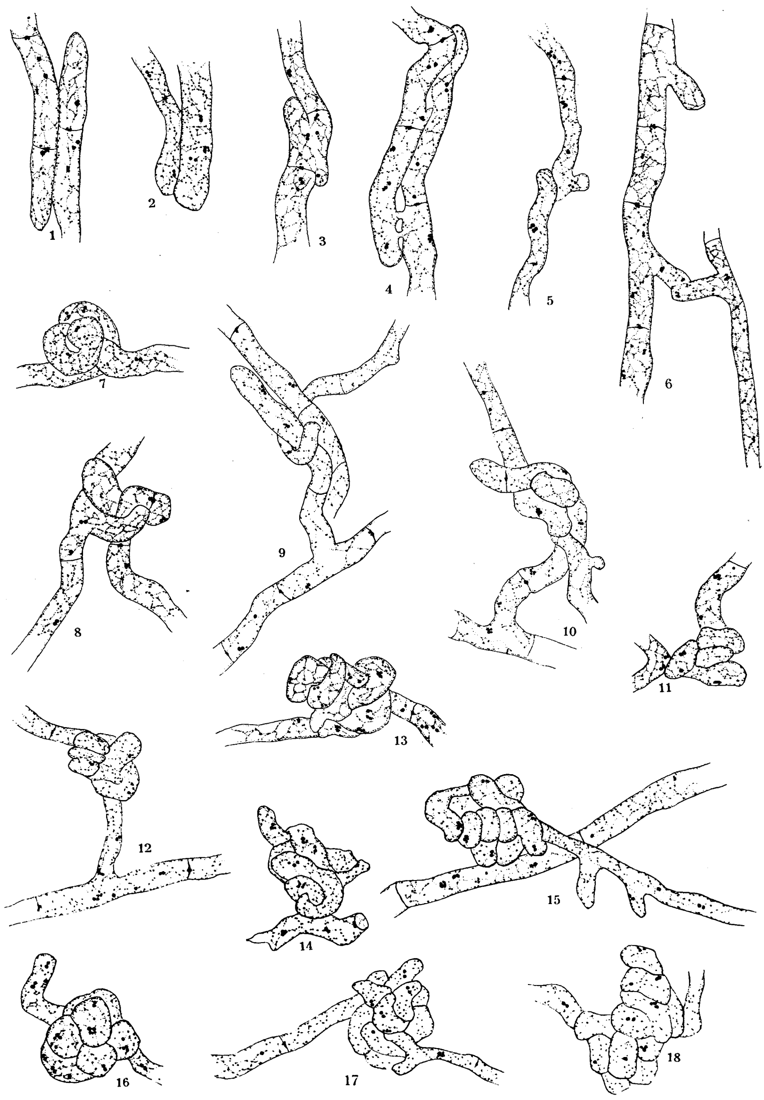
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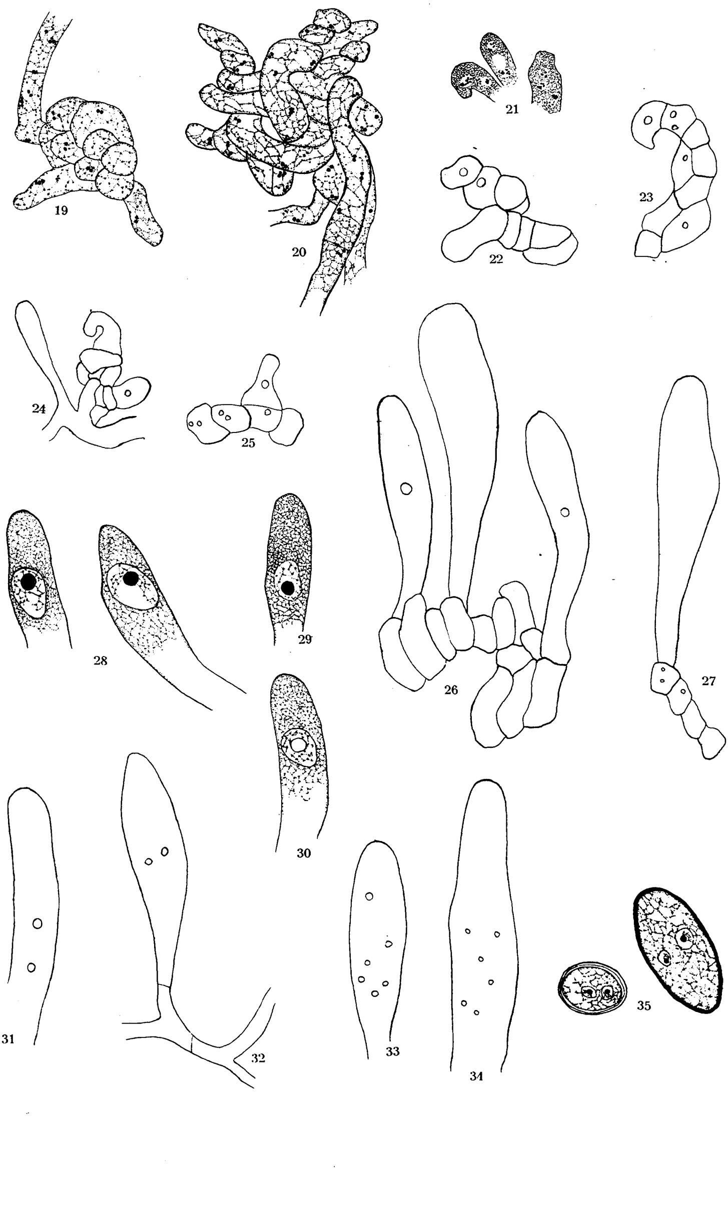
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SOME NOTES ON ALLOMYCES ARBUSCULA BUTLER

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This fungus is one of the water molds whose exact relationships have been in doubt, and which, as yet, have not been the subject of much serious investigation. Its saprophytic habit, general mycelial structure, and apparent life history indicate its connection with the Saprolegniales—if this group can be raised to the rank of an order as Coker suggests (2). In this order he places four families: the Saprolegniaceae, the Leptomitaceae, the Blastocladiaceae, and the Monoblepharidaceae. Gäumann (4) has Oömycetes as the order in which he includes five families: the Monoblepharidaceae, the Blastocladiaceae, the Ancylistaceae, the Saprolegniaceae, and the Peronosporaceae. Kanhouse (7) finds distinctive characters in this form and its relatives to suggest the order Blastocladiales in which she would place the family Blastocladiaceae. The varying systems are the result of the inability to accurately and definitely define the structural characteristics which are to determine the place of a species in its relation to others. This difficulty is enhanced by a lack of knowledge of the true nature of the various features of structure. Hence a clear description of the phylogenetic relationships and a natural system of classification is, as yet, next to impossible. Therefore, it seems best for convenience to adopt Coker's classification in which we find the family Blastocladiaceae composed of two genera, Blastocladia and Allomyces. In the first of these we find four species mentioned; *B. pringsheimii* Reinsch, *B. ramosa* Thaxter, *B. rostrata* Minden, *B. prolifera* Minden. Barrett (1) had previously associated these four species and included with them *B. strangulata* Barrett, which, for reasons we later consider, Coker places in the genus Allomyces and gives the name adopted throughout these notes. The same plant is also described by Coker and Grant (3) under the name

Septocladia dichotoma. Hence in the literature we find this one form labeled any one of the following names: *Blastocladia strangulata* Barrett, *Allomyces arbuscula,* Butler, and *Septocladia dichtoma.*

Up to 1923 with the publication of Coker's work on the Saprolegniaceae, *A. arbuscula* had been reported only from India by Butler, from Ithica by Barrett, and from the Philippines by Weston. Coker considers it rare in occurrence having found it only once at Chapel Hill. Harvey (5) reported it from Chapel Hill and also has it in his collection of Mississippi soils from which he kindly supplied us with material.

For reference throughout this paper we reproduce with some omissions Coker's description of the genus and species:

"Genus Allomyces: Plant small, slender, the short or long stalk not conspicuously differentiated; branches usually dichotomous, often verticellate in groups of 3–5, separated from the nodes by distinct and complete septa, not constricted at intervals; in vigorous cultures repeating the branching in the same way to form a complex plant. Sporangia oval, terminal, sympodially arranged, not rarely in chains of several often clustered by the shortening of the branches which continue the stem by one or more lateral buds beneath. Spores bi-ciliate at times, but the two cilia so closely approximated or fused as usually to appear as one. Resting bodies borne in the same way as the sporangia and of the same size and shape, at maturity enclosed in a thin hyaline sheath out of which they finally fall through an apical slit; the wall brown and conspicuously pitted; the whole representing a thin-walled oögonium completely filled with a thick-walled parthenogenetic egg, or resting sporangium as thought by Barrett.

A sparophytic aquatic of anomalous structure and differing from all the other Phycomycetes in the regular and normal septation of the plant body.

Species *A. arbuscula* Butler: Characters of the genus, threads extending about 4 or 5 mm. from the substratum of hemp seed (Coker uses ants) about 10μ thick, growing gradually more slender distally at each joint; joints of central region more elongated than those near the base, tips blunt, hyaline. Sporangia oval, spores escaping singly or at times, according to Barrett, in a vesicle that soon bursts, emerging through one or two usually apical holes or short papillae, spores biciliate, oval when swimming, with cilia apical, monoplanetic, amoeboid before encysting, 10μ thick when at rest; sprouting by a slender thread. Resting bodies appearing later than the sporangia but of the same size and shape; the conspicuous pits apparently sunken from the outside in regular fashion as in B. Pringsheimii, at maturity slipping from the thin clasping sheath; sprouting into zoöspores after a rest (Barrett). The thick wall is divided into two parts, an outerlayer pitted about 1.8μ thick and a homogeneous inner one about 1μ thick."

The uncertainty as to the details of the life history of *A. arbuscula* is due primarily to lack of knowledge of the true nature of the reproductive bodies observed. Apparently there are two groups of these and in observing this plant they constitute the most conspicuous features of its structure. The mature plant bearing its crop of resting bodies is easily recognized by its brick red color due to the presence of these reddish organs. The other group of bodies are the sporangia which have a lighter color. A given plant may produce either one or both sporangia and resting bodies. It is agreed the sporangia are asexual in their origin while the bodies which Coker calls "resting bodies" are oösporic in nature.

The exact time when the plant will develop sporangia seems to depend almost entirely upon external conditions, such as the presence or comparative lack of food, the amount of moisture present, and perhaps on the temperature. Most investigators have grown the plant on such media as sweet corn agar (Barrett, Kanhouse) while Coker used termite ants also. Our cultures have been maintained on boiled hemp seed and have appeared to thrive. Such a medium is easily prepared; the growing plants are removed from it with no degree of difficulty and the amount of nutrient supplied can be controlled with some measure of success. The observation of Kanhouse (6) that morphological development of such fungi is intimately related to external stimulii can be well demonstrated. However, we would regard our medium as superior to any of the agars in nothing but the convenience and simplicity of its manipulation.

Our first cultures were started over a year ago from three colonies. During these succeeding months we have varied the growth conditions over as wide a range as possible. At no time have we had difficulty with obtaining material in almost any stage of growth. New cultures have been started by touching the cut side of a bisected hemp seed with fragments of an active colony. These pieces of seed material are then placed cut side down in a Petri plate containing a quantity of distilled water sufficient to cover the plate to the depth of a millimeter. The plate is then covered and kept in a darkened place at a temperature not above 20 degrees Centigrade. Three or four days will result in well developed plants.

In the presence of comparatively large quantities of water and abundance of food with a temperature not below 15 degrees, immense numbers of sporangia were produced, arranged in long chains often sympodically upon long filaments of mycelium. No resting bodies appeared in the culture thus maintained for the period of a week. If, however, the food supply was allowed to run low or the quantity of water was reduced to the point at which portions of the plant were exposed to the air, resting bodies made their appearance while the production of sporangia gradually ceased. These resting bodies were produced in great numbers as long as any food was available or moisture present. To investigate the potential vitality possessed by the resting bodies the following procedure was tried; two sets of cultures were chosen eleven months ago—one of these sets was allowed to dry out slowly while the other was kept moist with sterile water. During the next nine months occassional inspection showed no change in the moist cultures except for the gradual disintegration of the mycelial mass indicating death of the plant. The dry cultures assumed the form of brick colored incrustations on the surface of the glass. The finger when touched to a colony came away tinged with a rust colored spot caused by free resting bodies adhering to the skin. At the end of the nine months' interval these dried masses were scraped into a test tube of sterile water and thoroughly broken up by means of a round ended glass rod. The tube was set aside a few minutes until the bottom appeared tinged with the reddish color of the resting bodies which had settled. The water was then decanted off and more sterile water added when the shaking and decanting processes were repeated. The third addition of water carrying the resting bodies was then poured into a sterilized plate containing hemp seed which had been boiled after the splitting process for fifteen minutes. The plate was then covered and set aside in a temperature of 16 degrees. Vigorous growth appeared in two weeks, the plants subsequently passing through the sporange-producing stage to the development of resting bodies during the succeeding three days. The same treatment was accorded the set of cultures which had been kept moist. These also germinated successfully after one week in the new medium. Some trouble was experienced with bacteria and protozoa of a few types, but these were easily eliminated by washing the cultures with distilled water at intervals after they were fairly well established. Changing the water occasionally prevented the foreign organisms from overrunning the cultures. Sterile water was used only with the idea of avoiding as much as possible the introduction of forms as yet absent from these particular cultures.

The results thus obtained indicate the correctness of the supposition that the resting bodies produced in the oögonia function as their name implies. But the length of time required for their germination is not necessarily a matter of months as implied by Barrett. It is true, however, that these bodies do not immediately germinate as none are ever found in the germinating condition near the colony which gave rise to them.

A close study of the mycelium reveals some complexity. In living plants one readily observes a difference in the contents of various hyphae. In some filaments the presence of immense vacuoles is conspicuous (fig. 1). These completely fill the axial region of the filament, giving it the appearance of being empty. In other hyphae the vacuoles are smaller, the cytoplasm is decidedly granular, and bodies of several different forms are present (fig. 2). In these latter types of filaments streaming of the cytoplasm has been observed when currents are seen in the outer region setting back toward the proximal end of the cell and returning through the center. All hyphae with granular contents do not exhibit streaming, however.

The plastides found in the hyphal contents are of more than one sort as to composition. There are large, nearly spherical bodies as large as 2μ in diameter. These bodies in the living hypha are slightly yellow and become brilliant red with triple stain. Reinsch (9) regarded them as "endogenously produced cells". Pringsheim (8) holds them to the waste products of metabolic processes. Both Pringsheim's and Reinsch's views are mentioned by Barrett (1). These bodies exhibit no internal structures as might suggest nuclei, nor do they contain granules of any sort. Hence Pringsheim's view seems the more reasonable. There are, however, bodies of nearly the same size as these red-staining plastids whose staining reaction is entirely different. These bodies are invariably light blue or lilac in tint and close inspection shows their outline to be irregular. They are usually centers from which strands of protoplasm radiate. From their position and general appearance we regard the mas nuclei. Occasionally larger ovoid bodies are observable which take very little stain, either triple or haematoxylin. The probability is strong that they are accumulations of fatty material.

At intervals there occur very slight constrictions in the hyphal wall at which points also are found the characteristic cross walls which Barrett (1) describes as bearing pores. This finding is not corroborated by any other worker as far as we can ascertain, and the present material exhibits nothing of the sort, either living or sectioned (fig. 3). In our observations the cytoplasmic content of the hypha on one side of the wall is entirely cut off from that on the other side. Of course ultra-microscopic pores may, and probably do, exist. But as far as available evidence goes, we have in this peculiarly septated hypha a multicelled structure. In Barrett's paper of 1912 (1) we note that the micrographs of his entire plant, figures 58 and 59, show the presence of sterile hairs while figure 57 has no indication of them and neither does his habit sketch, figure 12. Yet all these specimens are supposed to be typical of the species under discussion. Coker's *arbuscula* (2) lacks these hair-like filaments. We believe therefore, the question might be raised as to whether the author of the incomplete septation observasions was dealing with one species or had inadvertently used a form like *B. pringsheimii* or *B. rostrata* where there are sterile hairs and no septations. Coker (2) is quite clear in his observation that we have in *A. arbuscula* a multicelled mycelium.

At the points where cross walls are formed it will be observed that the hypheal diameter is increased forming a slight bulge either side of the wall. These enlargements could easily be due to a tendency to contraction of the cytoplasm acting to shorten the filament. No bulges are apparent at young cross walls but seem to be a development with age. Some change in cytoplasmic volume, therefore, in time serves to cause this apparent constriction. The direction of least resistance and therefore of the greatest change of shape is at right angles to the hyphal axis. But the added reinforcement of the cross wall prevents a shrinkage at points where it is attached. Thus any reduction in diameter is more apparent than real.

The basal cell from which a hyphal system is derived is quite difficult to make out on material grown on hemp seed. The cell is larger in diameter than the rest of the hypha. It is also much shorter and Barrett's description mentions rhyzoids (1), but we have not seen them. The hyphal cells vary in length; when growth is slow they tend to be short, while rapid growth results in long filamentous cells bearing branches, each cell constituting a considerable portion of the mycelium of one plant.

Under conditions which have not yet been worked out, the tip of a growing hypha begins to enlarge taking on a bulbous form. At the same time there is apparent a concentration of nuclei near the tip of the filament (fig. 4). The cytoplasm becomes lighter in appearance and lacks always the large vacuoles which are often visible in some filaments. The nuclei that may number a score or more assume positions equidistant from each other and in a region near the wall of the hypha. At this stage the bulbous development has resulted in an ovoid tip whose surface region is marked by the presence of these irregularly shaped nuclei which now appear to be connected to each other by strands of denser protoplasm (fig. 4). Much study might be expended upon the method of cross wall formation at this point in the development process. Apparently the first evidence of a cross wall cutting off the bulbous terminal from the filament is a line of granules extending from wall to wall (fig. 5). Whether or not a plasmal membrane has preceded the appearance of these minute solid particles is uncertain. From the material we have observed, we believe such to be the case as the cytoplasm in the sporange takes the haematoxylin more readily, and the line of demarcation between sporangial cytoplasm and that of the hypha is quite distinct, although there is no separating medium apparent. Through accumulation of granular material a solid partition is at last developed which takes on the character of the hyphal wall. This process may be repeated in the hyphal region immediately proximal to the first sporange. Successive repetitions of this process produce a chain of sporangia.

Thus far there has been no evidence of the peculiar furrowing process of spore development that is often seen in Phycomycetes. But after the appearance of the cross wall large vacuoles appear and the stranded structure disintegrates into masses of varying density indicating the cleavage furrows by which the cytoplasm is divided as shown by Barret (1). This author also describes the subsequent behavior of the zoöspores produced. They emerge from the sporangium through specially developed structures, papillae of dehiscence, of which there may be one or several on the walls of the sporange. Those we have seen are meniscus in cross section and as Barrett observes, are made up of two parts: an inner membrane surmounted by a convex hyaline elevation. The rupture of one or more of these papillae permits the meregence of the zoöspores in single file. These are uni-, bi, or tri-ciliate. The biciliate form is the normal one and Coker (2) would admit the triciliate forms as only bare possibilities.

Not all spores are discharged in some cases and those which are retained in the sporangium become amoeboid and remain in the sporange until they encyst (fig. 7). The empty sporangia are retained in position on the plant, often forming long chains of six or more, some of which have emptied sooner than others. No relation seems to exist as to the order in which these members of a chain shall release their spores.

It has not been our fortune to observe the zoöspores in the act of emerging but Thaxter (10) gives a short account of the ciliated spore and Coker (2) includes diagrams of the internal structure. It is not hard to find encysted spores in a culture and also many such in the process of germinating (fig. 8). The encysting wall is not marked nor of great thickness and is hyaline. Before germination, stained spores show a reticular cytoplasm. Two or three large vacuoles are evident as are a number of large granules. Since there is no great mass of undifferentiated protoplasm present, the entire contents of the spore may be a nucleus. There is usually a single body more or less refractive that, by its large size, may correspond to a nucleole. Spores are located whose entire contents is granular and a smaller body within this mass exhibits a reticulum. Spores sprout by hyphal extensions. Hence the possibility that, as the spore enters the germinating stages, the granular material is absorbed as the nucleus enlarges. Germination results in the extension of a slender thread of granular cytoplasm surrounded by a hyaline sheath. Also we have often observed spores whose contents have divided before the filamentous extension is produced (fig. 9). If chromosome material exists in distinct characteristic bodies anywhere in the structure of the organism one would expect it apparent at this stage. We do find several rather distinct granules in the spore contents especially at certain stages of germination. These are too small to exhibit shapes which would make possible the identification of any one chromosome. Yet these bodies might well function as such. For cytologists are practically united in the opinion that it is only the abnormal nucleus that lacks chromosomes.

In the usual progress of growth in culture, the sporangial period is followed by a later stage of growth characterized by the appearance of large numbers of resting bodies. Coker (2) suggests that they partake of the nature of parthenogenetic eggs. Since no other sex organs have been observed, if sex has dropped out of the life cycle, here is the only remnant of that process. And we assume sex to have disappeared to that point where antheridia have become totally undeveloped. Of course one may regard *A. arbuscula* as ascendant in the phylogenetic scale instead of degenerate. If such a view be taken, it is hard to account for the complex structure of these resting bodies. In early development they are practically identical with the sporangia which have preceded them. They exhibit the reticular cytoplasmic structure and regular arrangement of the nuclei enclosed in the ovoid terminal of the hypha. This likeness persists beyond the development of the cross wall. However, groups of these bodies never occur in chains for the reason that after the formation of a body at the hyphal terminal further growth occurs in the hypha by a lateral bud at the base of the resting body. Until further work is done on the cytology of the resting body we can go but little beyond the facts we have mentioned. But this question might be raised: from present knowledge of the nuclear material of the hypha, what is to prevent the formation of these resting bodies in chains similar to the sporangia? Their origin is the same; their method of development is apparently identical up to a very late stage of growth. Why then, might not the contents of a considerable portion of the distal end of a hypha break up into successive portions as happens with the sporangia? We feel the answer will be found in the behavior of the nuclear material of the resting body immediately prior to the formation of the cross wall. By some means these nuclei undergo an abnormal change. This could take the form of a reduction process which would be the natural thing to expect if this material were to form oöspores or eggs.

The next period of growth in the resting body is indicated by the appearance of a clear refractive wall within the membranous sheath which originally functioned as the filament wall and in which appear the papillae of dehiscence if the body is a sporangium. This new inner coat appears to be secreted from the outer cytoplasm. It attains some thickness before any indication of the characteristic pits appears. However, soon the density increases, and the indentations become evident. These pits are conical in longitudinal section with the wider diameter at the outside (fig. 11). These pits do not extend through the wall, but penetrate it to a region which can be made out below the pitted stratum and which is uniform in density. Coker regards these layers as separate walls (2). His reason for doing so is not quite apparent. In mature resting bodies the sporogenous mass is surrounded by a second membranous wall within the pitted coat. This membrane is easily observed in material that is slightly plasmolyzed.

As to the behavior of the mass of cytoplasm within this case, little that is definite can be said. The numerous darkly stained nuclei arranged peripherally are not evident in the mature resting body. The contents are uniformly granular, or, at most, marked with a few masses of granular structure a little more dense than the rest. However there can be found a group of resting bodies whose walls are completely formed, but whose contents consist of a couple of dozen spherical bodies which stain red in safranin and in living material are clear and slightly yellow. These may be fat globules. If these fatty accumulations appear in the later stages of development the question of what has become of the nuclear bodies cannot be answered. There is a group of bodies also whose contents resemble figure 12. These bodies exhibit markings of some form of cell division. In living material detached bodies are granular and fat-containing ones are never found free. Release of the resting bodies takes place by the rupture of the external membranous wall when the body floats free, and even the part of the heavy wall formed at the point of attachment to the hypha shows pits (fig. 11). Coker mentions the cracking of the pitted coat to release the material from which, he assumes, a new mycelium is produced (2). From the nature of the contents of the resting body and from the fact that the result of the germination of these contents is a form no different from that resulting from the germination of the zoöspores, we may safely conclude that these resting spores are not radically different in their make-up, unless some nuclear modifications take place in the zoöspores prior to germination. This also strengthens the hypothesis of parthenogenesis.

SUMMARY

1. A convenient method of raising *A. arbuscula* has been worked out.

2. Additional evidence of complete septation is provided.

3. The growth history of Coker's "resting bodies" has been studied providing further indications of their zoögonial nature.

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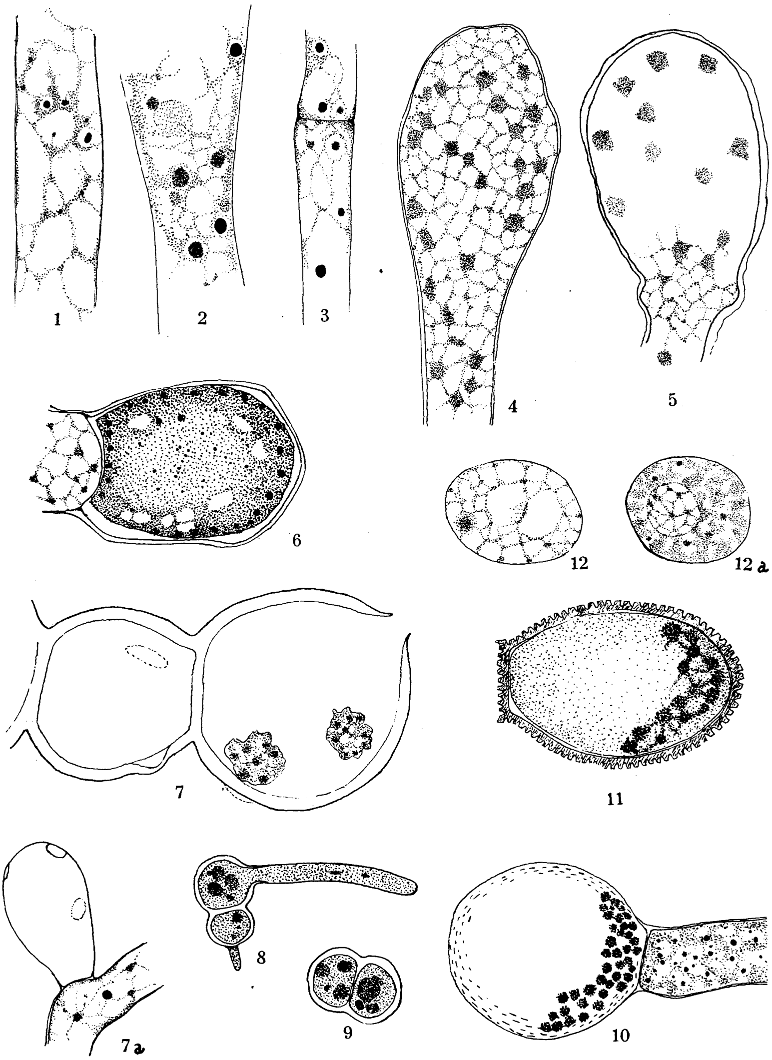
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EXPLANATION OF PLATE 8

FIG. 1. Vacuolated cytoplasm in hypha. × 1900. Haematoxylin stain.

FIG. 2. Types of hyphal plastids. × 1900. Triple stain.

FIG. 3. Typical cross-wall. × 1900. Triple stain.

FIG. 4. Developing sporange. × 1900. Safranin and licht grün stain. The peripheral arrangement of the nucleii is often more pronounced than is shown here.

FIG. 5. Granular origin of the cross-wall of sporange. × 1900 Triple stain.

FIG. 6. A later stage in sporange development. × 950. Haematoxylin stain. The arrangement of nucleii is very evident here as is also the difference in staining reaction of contents of the sporange and of the hypha.

FIG. 7. Amoeboid zoöspores entrapped in sporange. × 950. Living material. The nature of the rupturing process of the papillae of dehiscence may be easily made out as well as something of their structure.

FIG. 7a. An empty sporange. × 440. Living material.

FIG. 8. Germinating spore. × 900. Living material.

FIG. 9. Spore which has divided without development of a process. × 900. Living material.

FIG. 10. Young resting body with first indications of pitted wall. × 1900. Living material. Contents not drawn.
Contents not completely shown.

FIG. 11. Mature detached resting body. × 1900. Triple stain. Contents not completely shown.

FIG. 12. Spores found in mature resting body. × 2300. Triple stain.

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. III. LOBELIACEAE, CAMPANULACEAE, CUCURBITACEAE[1]

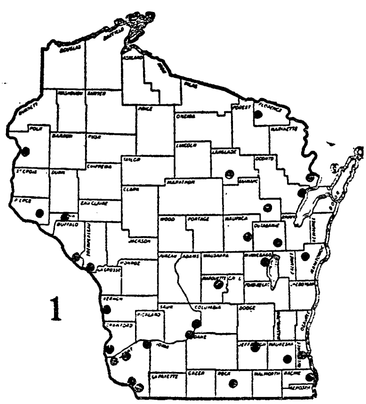
KENNETH L. MAHONY

LOBELIACEAE

This family is represented in Wisconsin by the genus *Lobelia*, with six species.

L. CARDINALIS L. (fig. 1) This species is general over the state with the exception of the extreme northern part.

L. SYPHILITICA L. (fig. 2) This is general over the state except in the northern part. In common with many other



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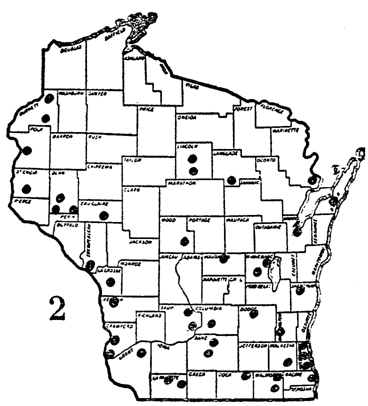

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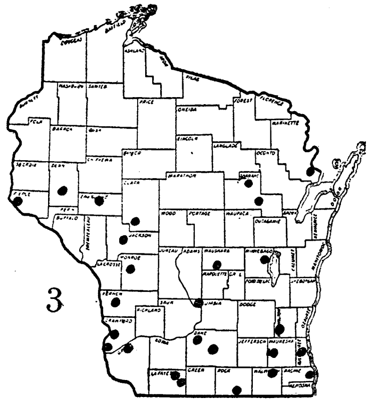
plants of southern range it is found in the valley of the Wisconsin River north to Lincoln County and in the St. Croix River valley north to Burnett County.

L. SPICATA Lam. (fig. 3) Is of southern range in Wisconsin, being found chiefly in the southwestern part of the state. However, var. HIRTELLA Gray (fig. 4) tends to run northward in the eastern part of the state to Marathon and Marinette Counties.

[1] The ranges presented here are based on the collection in the Herbarium of the University of Wisconsin and that of the Milwaukee Public Museum.



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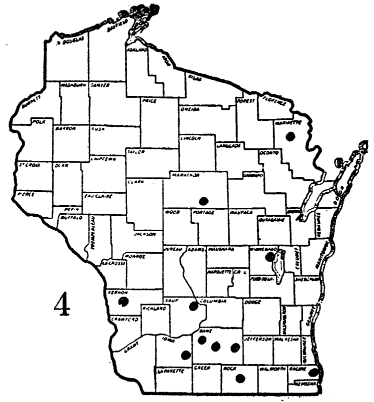

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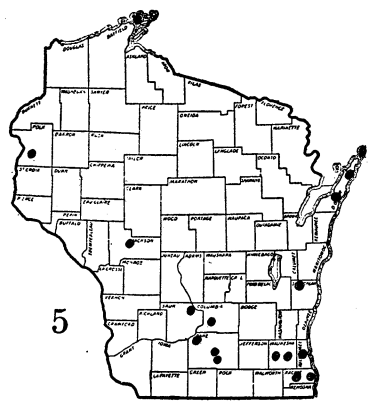

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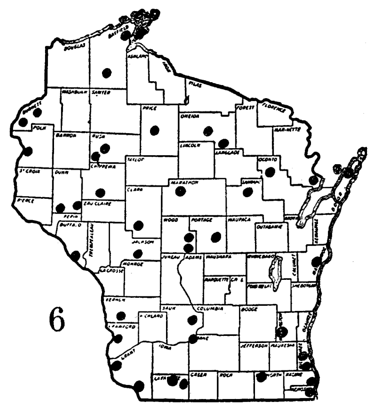

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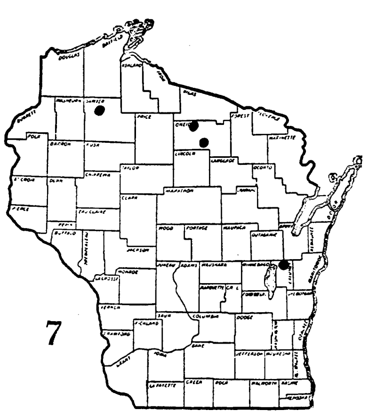

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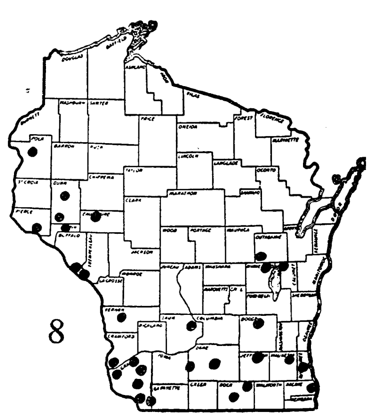

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L. KALMII L. (fig. 5) This occurs principally in the southern part of the state, centering in Dane, Sauk and Columbia Counties along the Wisconsin River and also in Milwaukee, Waukesha and Racine Counties in the eastern part of the state. It has also been found in Door County and as far north as the Apostle Islands and should be looked for in the lake region of northern Wisconsin.

L. INFLATA L. (fig. 6) Is found to be quite common all over Wisconsin.

L. DORTMANNA L. (fig. 7) This species is entirely of northern range, being found in the lake regions of Sawyer, Oneida and Calumet Counties.

CAMPANULACEAE

This family is represented in Wisconsin by five species of the genus *Campanula* and one species of the genus *Specularia.*

CAMPANULA RAPUNCULOIDES L. A garden escape; Racine (J. J. Davis, 1879). Well established, according to Wadmond.[2]

C. AMERICANA L. (fig. 8) Occurs in the southern part of the state and also the western part along the Mississippi and St. Croix River vallies as far north as Polk County. This is a range that is characteristic of many plants of southern Wisconsin.

C. ROTUNDIFOLIA L. (fig. 9) Is rather general throughout the state.

C. ULIGINOSA Rydb. (fig. 10) This is of northern range in Wisconsin.

C. APARINOIDES Pursh. (fig. 11) Is found in the southern part of the state and north along the Wisconsin River to Wisconsin Rapids. It has also been found in Polk and Burnett Counties.

While there are well developed extreme specimens of *C. uliginosa* and *C. aparinoides* which are quite distinct, there are many intermediates which cause some confusion. Ordinarily the little-branched *C. uliginosa* has large flowers and linear leaves, while *C. aparinoides* is more branched,

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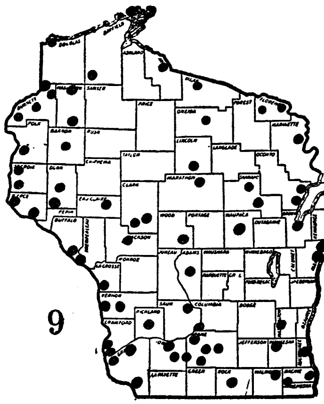
[2] Trans. Wis. Acad. Sci., Arts and Let. 16: 869. 1909.



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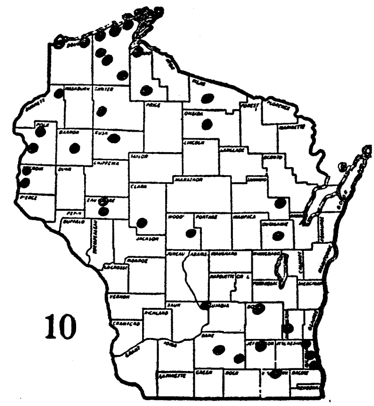

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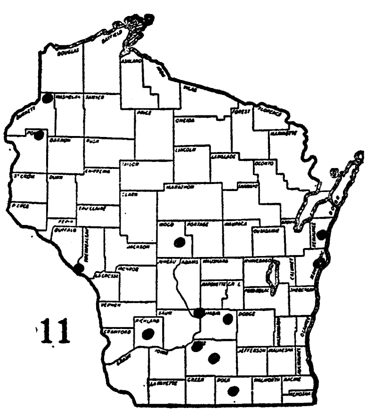

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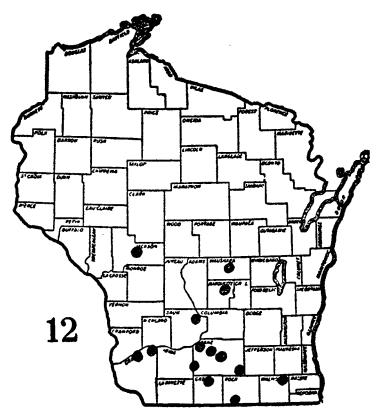

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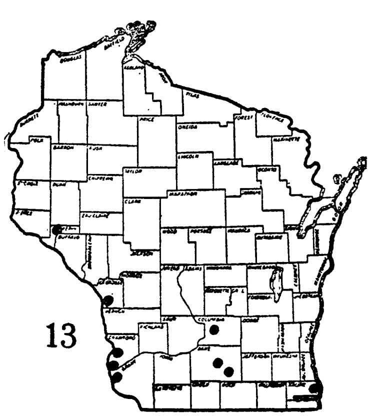

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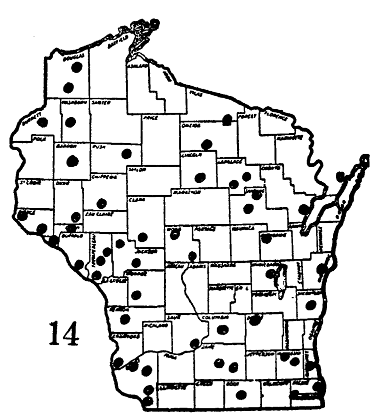

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with small flowers and lanceolate leaves. Certain individuals which we term intermediates have small flowers and linear leaves, or large flowers and lanceolate leaves, and are very difficult to place. The characters that were principally relied upon in this study were those given by Fernald and Wiegand, Rhodora 25: 214. 1924.

C. aparinoides: naked portion of peduncle 0.3–3.5 cm. long; flowering calyx 1.3–3.8 mm. long, its lobes 0.7–2 mm. long; capsule 1.2–2 mm. long.

C. uliginosa: naked peduncle 1–6 cm. long; flowering calyx (3–) 4–6.7 mm. long, its lobes 2–4 mm. long; capsule 3.2–5 mm. long.

SPECULARIA PERFOLIATA (L.) A. DC. (fig. 12) This species is of southern range in Wisconsin, running north as far as Jackson County in the western part of the state.

CUCURBITACEAE

This family is represented in this state by two genera, each with one species.

SICYOS ANGULATUS L. (fig. 13) Comparatively few collections have been made of this species. These collections have been made in the southern part of the state and along the Mississippi River as far north as Pepin County.

ECHINOCYSTIS LOBATA Torr. & Gray. (fig. 14) Is found to be quite general over the state. It is extremely abundant in the valley of the Mississippi River.

A STUDY OF TWO LIMESTONE QUARRY POOLS

EDWARD JOSEPH WIMMER

INTRODUCTION

Very little work has been done in the United States on the chemical and plankton conditions in pools and ponds. Scott (1910) made a study of the fauna of a solution pond. Reed and Klugh (1924) studied the hydrogen ion concentration of a granite and a limestone pool near Kingston in the Province of Ontario. In Europe, more attention has been given to this field. Griffiths (1916, 1922) and Atkins and Harris (1924) have studied the heleoplankton and chemical factors in quarry pools and ponds. Among the many other workers are Alexander, Rylov, Nordqvist, Scähferna, Fric, Diefenbach, and Sachse.

This paper is based upon a study of the physical, chemical, and plankton conditions of two limestone quarry pools near Milwaukee, Wisconsin. The larger of the two, which shall be called the Wauwatosa pool, lies near the western city limits of Milwaukee, in a recently annexed portion of land, adjacent to the suburb of Wauwatosa. It is the site of an old limestone quarry, in which operations ceased about thirteen years ago, and which, since then, has been slowly filling with water as there is no outlet, until it is now 23 meters (75 feet) deep. It is roughly rectangular in shape with the long axis in an east-west direction, and covers an area of approximately 1.36 hectares (3.36 acres). The walls on all sides are precipitous, and rise on the south side of the pool to a height of about 5 m. The height of the walls decreases toward the north side where it is only about 1 m. above the surface of the water. On all sides the walls descend abruptly to a depth of 5 m. except for a few recently submerged shallows, which are small in extent. The limestone about the pool is overlaid by glacial gravel, which forms a moraine on the south side, the crest of which is about 200 m. from the quarry. The other sides are comparatively low. The drainage into the pool is primarily from the moraine to the south. Except for dwellings on the crest of the moraine, there is little contamination from civilization. Much carbon, however, settles on the pool, from smoke of a railroad a few city blocks to the north, and from factories nearby. The pool receives plenty of sunshine due to its east-west position, and to the lack of vegetation along the eastern and western shores.

Along the sides is a ledge about 5 m. below the surface of the water. This ledge is very narrow along the eastern three-fourths of the quarry, but forms the entire floor of the quarry at its western portion. From this ledge the bottom descends abruptly again to a ledge at a depth of 15 m., which is the depth of the larger portion of the pool. In the northeastern portion, at the site of the former "quarry hole" is a large area, about one-fifth the area of the pool, which is 23 m. deep. The bottom of the pool to within a year ago was comparatively free from ooze. A sample of the bottom brought up with a mud dredge showed the greater part to consist of coal dust or carbon, and to be approximately about two inches in thickness. In September 1926, clay was emptied into the pool. Within a comparatively short time, it became distributed over the bottom of the pool.

The rise of the water level of the pool during the time it was studied is of interest. A photograph taken of the pool in May 1921 shows the water level to be about 9 m. below the level of August 1925 when this study was begun. Between August 1925 and March 1928 the water level rose about 2.1 m.

The study of the second pool was begun in September 1926. This also is an abandoned limestone quarry, about five miles to the northeast of the one just described. This pool is on the south limits of North Milwaukee, and will be called the North Milwaukee pool. This body of water is about one-third the size of the Wauwatosa pool, and is also well isolated from contaminating sources. The walls rise vertically from the bottom on all sides. The average depth is about 4.5 m. The deepest place in the pool is 5.5 m. The water level is less than 1 m. below the level of the solid rock. This is covered with glacial gravel, overgrown on all sides with grass. On the western side (the pool's long axis is in a north-south direction) the gravel forms a ridge about 3 m. high, with steep sides. There is little vegetation on the shores except for a clump of trees in the southeast corner and a few low wild crab trees near the center of the west shore. The other shores are low. The eastern side has a low dike to prevent a creek about 5 m. distant from overflowing into the pool in times of flood. The level of the creek is slightly lower than that of the pool and lies in solid rock. The bottom of the pool is composed of soft black ooze, but its depth is not known. About five years ago almost all of the water was pumped from the pool after the creek had overflowed into it. At this time the dike was built. In winter ice is harvested from this pool, but not from the Wauwatosa one. The smaller pool is about eight to ten years old.

Methods

Practically all of the samples from the Wauwatosa pool were taken in the open water at the spot where it was deepest (23 m.) and about 10 m. from shore. This was made possible by the use of a small flat-bottomed boat kindly loaned by Mr. W. Manegold, who lives on the property, and with whose kind permission and hearty cooperation this work was made possible. At times it was impossible to use the boat, and samples were then taken from the southwestern portion where the wall was vertical for about 5 m. Samples were taken as far from shore as was possible by pushing the line from the shore with the aid of a plank a little more than a meter long. Samples from the North Milwaukee pool were taken in the same manner from a point near the middle of the west shore. During the winter, samples of the North Milwaukee pool were taken from the center of the pool. So far as possible samples were taken during the same time of the day. This was between nine and twelve a. m.

All of the limnological apparatus was loaned by the Wisconsin Geological and Natural History Survey, through the courtesy of Professor C. Juday, under whose supervision and guidance this work was done.

The net plankton was collected by means of a closing net with No. 25 bolting cloth (Juday 1916). Hauls were made from 0 to ½ m., ½ to 1 m., then 1 m. hauls to generally 5 m. and in the Wauwatosa pool further hauls of 5 m. each to 20 m., and from 20 to 23 m. During 1927 horizontal surface hauls were made. One was just below the surface while the second haul was made about 10 m. below the surface. Each of these hauls of the net was for a distance of 2 to 3 m. The catch was killed and preserved immediately, and before counting, was diluted to 20 cc.

A Sedgwick-Rafter counting cell was used in making the plankton counts. The plankton in the entire cubic centimeter contained within the cell was counted by the aid of a mechanical stage, for such organisms as were not found in great numbers. The abundant organisms were counted by enumerating twenty squares with a Whipple micrometer (Whipple, 1927). Entomostraca, when in small numbers, were counted by looking at the total catch with a hand lens. All of the counts were computed on the basis of the number of organisms per liter.

Temperatures were taken with a Negretti and Zambra deep sea reversing thermometer. It was generally found necessary to take temperatures for every meter to 5 m., and often this procedure had to be continued to 10 m. Then readings were made at 5 m. intervals to the bottom, and intermediate readings were taken whenever necessary.

The turbidity of the water was taken with a Secchi disc 10 cm. in diameter, and the depth at which it disappeared was noted.

Dissolved oxygen was determined according to the modification in Standard Methods of Water Analysis (1925) of the Winkler Method (Winkler, 1888). Carbon dioxide was determined by the Seyler method as given by Birge and Juday (1911).

The hydrogen ion concentration was determined colorimetrically using cresol red (pH 7.2 to 8.8) and thymol blue (pH 8.2 to 9.8) as indicators and making a comparison with the Clark Color Chart of Indicators (Williams and Wilkins Co. 1922).

Nitrogen determinations were made as directed in Standard Methods of Water Analysis. Free ammonia, organic nitrogen, nitrates, and nitrites, were determined. Nitrogen determinations were not begun until May 1927.

All of the chemical work other than oxygen, carbon dioxide, and hydrogen ion concentration was done in the laboratory of the Wisconsin State Laboratory of Hygiene, and thanks are due to Dr. W. D. Stovall and to Dr. M. S. Nichols for permission to use the laboratory. To Dr. B. P. Domogalla, Biochemist for the City of Madison, the author is much indebted for guidance and assistance in all of the chemical analyses in the laboratory, and also in assisting in the transportation of the samples of water to Madison.

Soluble and total phosphorus were determined by the modification by Domogalla of the method of Juday, Kemmerer and Robinson (1927).

Chlorides were determined as directed in Standard Methods of Water Analysis.

Soluble silica was determined by the Atkins modification (1923) of the colorimetric method of Dienert and Wandenbulcke (1923).

The organic matter of the centrifuge plankton was determined by centrifuging one liter of water in a Foerst electric centrifuge (Juday 1924 and 1926). The organisms from a liter of water (concentrated to 4.5 cc. of water left in the bowl of the centrifuge) were transferred to weighed platinum dishes of 8 cc. capacity. After drying at 60°C. for 24 hours, the dishes were cooled in a desiccator and the dry weight was ascertained. They were then ignited in an electric furnace and after cooling were again weighed and the loss on ignition was determined. Since the centrifuge bowl contained 4.5 cc. of water, the amount of volatile matter in solution in the water must be deducted from the loss on ignition. This factor was found by determining the loss on ignition of 10 cc. of the centrifuged water, and the amount of such "blank" volatile matter in 4.5 cc. was subtracted from the loss on ignition of the centrifuged plankton.

In addition to the liter of water centrifuged for organic matter, 500 cc., or sometimes 250 cc., were centrifuged and diluted to 10 cc. for counts of the nannoplankton organisms which escape through the meshes of the closing net.

TEMPERATURES

A comparison of the temperatures of the surface water with the monthly meteorological tables issued by the Milwaukee office of the United States Weather Bureau shows that the water temperature increases more rapidly than that of the air, and that it cools more slowly. The high specific heat of water also prevents its showing as great variations as are shown by the air. In the spring the heat absorbed during warm periods is not dissipated to any great extent during the cool spells so that the water continues to increase in warmth at a comparatively uniform rate.

In the fall the water continued to cool until it reached a temperature near 0°C. This temperature was not reached in the Wauwatosa pool until early in December; but in the North Milwaukee pool, since there was a smaller volume of water to be cooled, the temperature reached this point as much as two weeks earlier. On the first quiet, cold night, ice formed on the pool. This occurred for the Wauwatosa pool on December 18, 1925, on December 4, 1926, and on December 20, 1927. The smaller pool froze on November 13, 1926, and on December 8, 1927.

The ice left the smaller pool earlier than it did the large one for there was less water to be warmed. Ice left the North Milwaukee pool on March 13, 1927 and on March 20, 1928. The large pool was free of ice on April 17, 1926, March 17, 1927, and March 28, 1928. The maximum temperatures at the times the pools were visited was 24.0° on July 10, 1926 for the Wauwatosa pool, and 25.7° on July 16, 1927 for the North Milwaukee one. The minimum surface temperature for the large pool was 1.5° on January 3, 1926 while for the smaller pool it was 0.4° on January 2, 1927.

The Wauwatosa pool in 1925–1926 showed typical lake conditions in regard to temperature. At the beginning of August, 1925, the thermocline or layer of rapid change of temperature began at about 5 m. On August 22 when the boat was used for the first time, the top of the thermocline was at 6.5 m. The thermocline continued to 12 m. with a temperature change from 21.5° to 5.7°. On September 3 the temperature in this layer did not change to any extent.

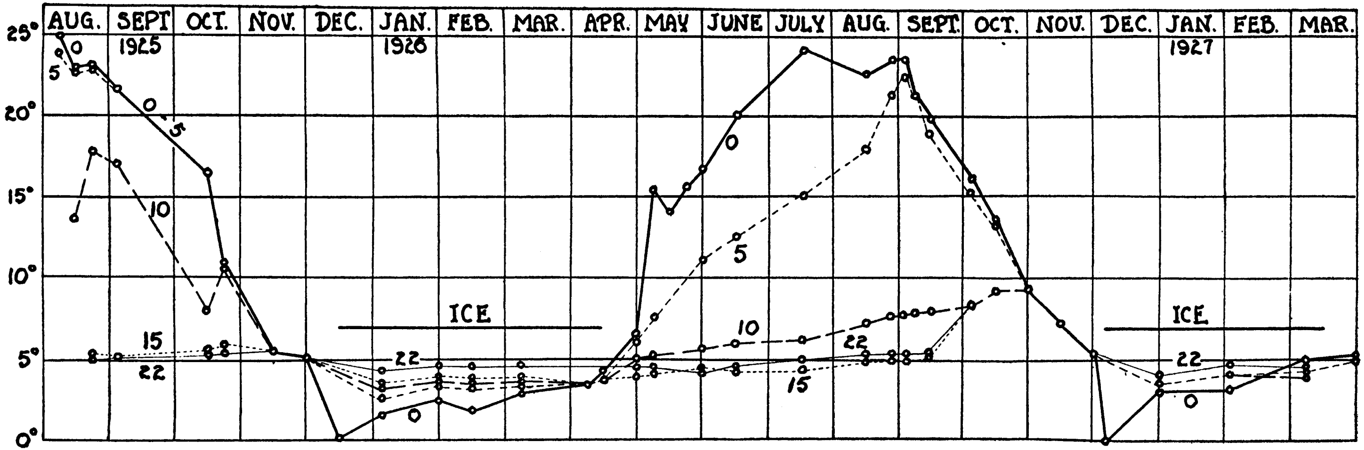

Fig. 1. Seasonal changes in temperature, expressed in degrees centigrade, at various depths in the Wauwatosa pool. The depths are indicated in meters by the figures attached to the curves.

The epilimnion, or layer above the thermocline, had cooled a degree (21.0°). The hypolimnion or layer below the thermocline began at 12 m. as before, with a temperature of 5.7° which was uniform thence to the bottom (23 m). By October 10 the surface had cooled to 16.5° bringing the epilimnion down to 8.5 m. The thermocline continued as before to 12 m. with the same temperature. On October 24 the surface layers had cooled uniformly to 10.9°, down to a depth of 11 m. at which level the temperature was 10.4°. This marked the lower limit of the epilimnion. Since the temperature of the hypolimnion remained constant, this narrowed the thermocline to only one meter with a fall in temperature of 4.5°. On November 14 the temperature was uniform from the surface to the bottom, namely 5.5°. On November 26 it had further cooled one-fourth of a degree. Ice formed on December 18, to a depth of one inch or 2.5 cm. By December 24 the ice was 2½ inches or 6.3 cm. thick and on January 2, 1926 it was 6 inches or 15 cm. thick. During the time observations were made, the ice reached a maximum thickness of 15 inches.

During the winter the water at a depth of 23 m. maintained a temperature between 4.0° and 5.0°. At 10 m. and 15 m. the temperature remained near 3.5°, while at 5 m. the temperature slowly rose until in February, 1926 it was almost the same as that for the 10 and 15 m. levels. The surface in the meantime had also become warmer, so that by the second week in April, when the ice left the pool, the surface water was practically the same as that for the rest of the levels. (Fig. 1).

With the increase in the length of the day in spring and a consequent increase in the number of hours of sunshine, the surface water warms very rapidly. At this time the temperature of the water is slightly more than 5.0°, and, being of a lower density than the water beneath it (which is close to 4°), tends to float on the surface. This prevents winds and convection currents from mixing it with the lower water so that the warm surface layer, or epilimnion, is formed. (Birge 1908). This layer was not clearly marked off until May. On May 9 it was only 1 m. thick. Below it came the thermocline which extended to 5 m. with a fall in temperature from 7.7° to 3.7°. On May

29 the upper layer was still one meter in thickness but the thermocline extended to 7 m. By June 22, 1926 the surface water had warmed to 20.0° and the epilimnion extended to 4 m. The thermocline had its lower level at 10 m. with a temperature of 8.2°. The hypolimnion had been warming up slightly. This condition continued for the summer with the epilimnion increasing in depth and warming slightly. The coldest water was near the 18 m. level where the temperature was below 4.9° at all times. (Fig. 2).

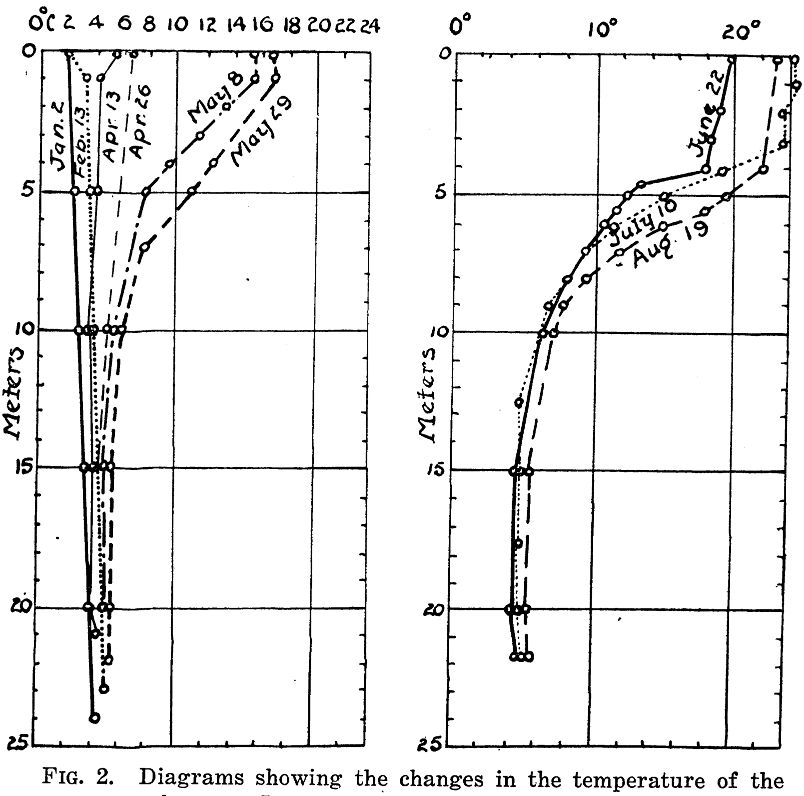

FIG. 2. Diagrams showing the changes in the temperature of the upper water between January 2 and August 19, 1926 in the Wauwatosa pool.

After September 16, 1926, clay was emptied into the pool as already stated, which warmed the entire hypolimnion and raised its upper level to 8 m. The entire water of this lower layer had a temperature of 8.4°, and it steadily warmed so that the overturn, or period of uniform temperature, was brought on much earlier than usual. (October 30).

During the summer of 1927 the boat could not be used so that bottom temperatures of the deep water were unavailable. When it was used again in September 1927, the bottom temperature was the same as that for the 5 m. level. This was probably due to the fact that clay was still being emptied into the pool and continued to keep the lower water at a temperature higher than usual.

The temperatures of the North Milwaukee pool were substantially the same from surface to bottom, since the pool showed no stratification. This condition is typical for small, shallow lakes.

TURBIDITY

The turbidity of the water as measured by the Secchi disc, corresponded in general with the plankton growths at the time. In the case of the phytoplankton, an increase in numbers will increase the turbidity and so cut off the penetration of the sun's rays to the deeper waters and thus limit the growth of these organisms to the upper water. Since the North Milwaukee pool had at nearly all times a heavier growth than the large pool, the turbidity was also found to be higher than that for the Wauwatosa pool. The deepest level at which the disc disappeared in the North Milwaukee pool was 2 m. in July and September 1927, and in February 1928. This was the minimum turbidity. The greatest turbidity occurred in October 1927 and March 1928 when the disc disappeared at 0.5 m. The Wauwatosa pool had a much clearer water, in spite of the fact that clay was emptied into it. The minimum turbidity was found in August and September 1926, before the clay altered conditions. At this time the disc disappeared at 10 m. Immediately afterward, the disc was lost to sight at 6 and then 3 m. in October. Coincident with this, however, was an increase in the growth of plankton. The greatest turbidity in the large pool was found on November 30, 1926 when the disc disappeared at 0.75 m. At this time there was a heavy diatom growth and clay was still being dumped into the pool.

Chemical Results

Oxygen. The story of dissolved oxygen for the Wauwatosa pool is very similar to that of the temperature, and is very much in accord with the findings of Birge and Juday and of other workers on Wisconsin Lakes. (Fig. 3).

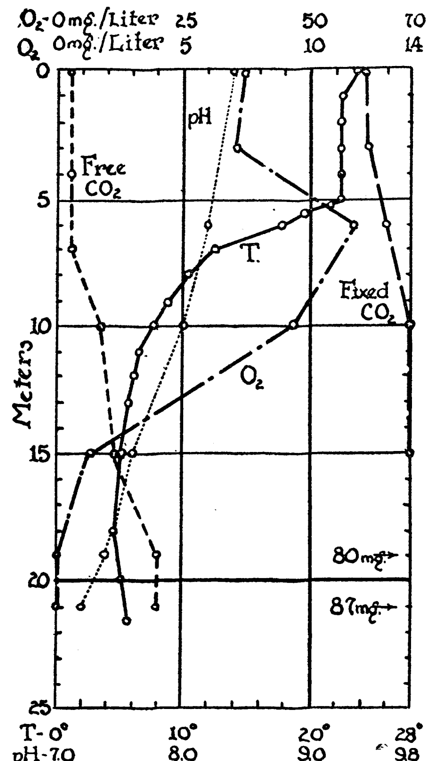

Fig. 3. Vertical distribution of the dissolved gases in the Wauwatosa pool on September 2, 1926.

Oxygen determinations were made in October 1925 and were then resumed in March 1926. In October 1925 the bottom water contained no free oxygen. The March determination showed no oxygen to be present in the bottom water, so that whatever had been acquired by the overturn of the fall had been used in the process of respiration and oxidation. Since the covering of ice prevented the circulation of water, the lower water remained without oxygen until the spring overturn. By April 26, 1926, the bottom water had acquired slightly more than 2 mg. per liter of oxygen or 2 p.p.m., and this steadily rose until May 8 it reached its maximum of 3.3 p.p.m. By this time the epilimnion had formed, effectively cutting off the lower water from contact with the air, and in this manner depriving it of further oxygen. The oxygen in the lower water was gradually consumed until by July 10, it had again disappeared in the water below 19 m.

With the dumping in of clay in the latter part of September, oxygen was brought to the lower water, probably partly by absorption to particles of clay and partly by carrying down some of the surface water. The amount of oxygen at the lower levels at once rose and soon was the same as that at 10 m. With the overturn in the fall, all layers contained oxygen, ranging from 80 to almost 100 per cent saturation. The bottom water now continued to be supplied with oxygen due to the dumping of clay, which continued for a few weeks after the ice had formed. In this way the amount of oxygen did not decrease in the bottom water as it had during the winter of 1925–1926. During the spring of 1927 and during most of the summer the bottom water could not be investigated due to the leaky condition of the boat. When a test was made on October 10, 1927 before the fall overturn, the bottom water contained 5.5 p.p.m. of oxygen as compared to 1.0 p.p.m. the year before. It must be remembered that clay was continually being emptied into the pool about 150 m. from the deepest portion.

The North Milwaukee pool presented no such conditions. It was found that the temperatures varied little between the surface and bottom. The same was true for oxygen. The greatest difference between the surface and the bottom was on March 12, 1927 when the surface held 14.7 p.p.m. of oxygen in solution as compared with 6.0 p.p.m. for the bottom water. Unlike the larger pool, the North Milwaukee pool reached and even exceeded saturation with oxygen, several times during the year. The maximum surface saturation was on November 26, 1926 with 138.1% saturation or 18.7 p.p.m. of oxygen. A similar high value was reached on December 7, 1927 with 135.3% or 19.3 p.p.m.

The minimum saturation percentage was found in October of both years—63.9% or 6.62 p.p.m. in 1927 and 44.9% or 4.5 p.p.m. in 1926. The maximum saturation is not unusual, for Birge and Juday (1911) report a saturation for Knight's Lake, Wisconsin of 364.5% and others have found similar conditions to exist at times.

Carbon dioxide. With regard to the carbon dioxide, the Wauwatosa pool is again found to be comparable to some lakes. With the spring overturn the amount of fixed carbon dioxide was practically the same from surface to bottom. As the stratification of the water progressed, the amount of fixed CO_2 increased in the bottom water because of the accumulation of free CO_2 which permits a greater degree of solution of the carbonates. In August and September, 1926 the bottom water contained 85 and 87 p.p.m. of fixed CO_2, respectively, while the surface water at this time had 57 and 52 p.p.m., respectively. (Fig. 3) With the dumping of clay in the latter part of September the free CO_2 disappeared from the bottom water and the amount of fixed carbon dioxide decreased as a result. With the fall overturn, the water again became uniform from surface to bottom with respect to fixed CO_2. During the winter the bottom water contained a larger amount of fixed CO_2, but the increase was not more than 2 p.p.m.; before the ice had left the pool a decrease in the amount of fixed CO_2 at the bottom was found, so that there was no real gain during the winter. The difference between the surface and bottom during the winter was very slight.

The free CO_2 followed in a general way the course of the fixed CO_2. This was particularly true for the bottom water, when in August 1926 there were 30 p.p.m. of free CO_2, which was the maximum for the year. This corresponded with the maximum of 85 p.p.m. of fixed CO_2. The amount of free CO_2 in the surface water gradually diminished until neutrality to phenolphthalein was reached in September. After clay was emptied into the pool, the surface water contained no free CO_2 except in December 1927 and March 1928 when 5.5 and 4 p.p.m., respectively, were present.

The North Milwaukee pool as a whole contained more fixed CO_2 than the Wauwatosa one. The maximum was reached on December 11, 1927 with 94 p.p.m. of fixed CO_2. The variations throughout the year were also much greater in extent, reaching a minimum of 40 p.p.m. in October 1927. Determinations of the fixed CO_2 in the bottom water of the North Milwaukee pool were not made during the summer. In October 1927 when they were made, the amount was the same for the surface and bottom, namely 85 p.p.m. During the summer of 1927 there was no free CO_2. in the surface water. This was probably due to its utilization by algae during the process of photosynthesis.

Hydrogen ion. The study of the hydrogen ion concentration has played an important part in ecology. Shelford (1923) and Jewell and Brown (1924) studied the reactions of fish to varying concentrations of the hydrogen ion. Juday, Wilson, and Fred (1924) studied the hydrogen ion concentration in various lakes deep enough to permit stratification. The lower levels were found to have a lower pH than the upper, due to decomposiiton in the former and photosynthesis in the latter. Noland (1925) found that ciliates exhibit a tolerance to rather a wide range of pH. He also found decided diurnal variation due to photosynthesis during the daytime. Philip (1927) also found a wide diurnal variation in a Minnesota lake and a horizontal variation depending on the proximity to clumps of plants and on the distance from the littoral region. Reed and Klugh (1924) found a variation of pH from 7.6 to 9.2 in a limestone pool in October and a biota distinct from that of a neighboring granite pool with a variation of pH from 6.2 to 6.8.

In the Wauwatosa pool the pH of the surface water varied from 7.8 to 8.8, being highest in September 1926, and lowest in March 1927 under the ice. In March 1928 the same value was reached with 4 p.p.m. of free CO_2. present, although for the previous year there was no free CO_2. in March. The bottom water varied between pH 7.2 and 8.6. The low value was found in September 1926 when there were 20 to 25 p.p.m. of free CO_2 and no free O_2 present. (Fig. 3). The high value came in 1926 just after the overturn on November 30. After the ice was formed the pH of the bottom water became lower, but did not vary more than pH 0.2 from that of the surface water. During 1927 the lower water did not reach as low a pH value as it had in 1926 because clay was dumped in as stated above.

The surface of the North Milwaukee pool varied between pH 7.6 and 8.9; the greatest variations were found in the spring and fall. The maximum was found on October 30, 1926 and the minimum on March 30, 1927. The lower water, except during the spring and fall overturn, had a lower pH value than the surface and varied between 7.4 and 7.8.

Chloride. The Wauwatosa pool had uniformly about 20 p.p.m. of chloride during the summer of 1927. The determination of the chlorides was started in February 1927. The high values in the larger pool may be attributed in part to the chlorides brought in with the clay. (This may also be true for the soluble silica, next to be discussed.) During the winter the chlorides rose to 21 p.p.m. Just before the ice melted the chlorides in the surface water decreased. In March 1927 and 1928 there was a decrease of 7 to 8 p.p.m. This seems to be due to the melting of the ice and a consequent dilution of the water under the ice. A sample of the January ice on melting was found to contain only 25 per cent of the amount of chloride found in the water just beneath it. The bottom water had a lower chloride content than the surface during the summer, but with the fall overturn it approached the same concentration. Throughout the winter it remained lower than the surface except in February 1927 when it was 4 p.p.m. higher than the surface.

The North Milwaukee pool did not show such a high chloride content, averaging about 12 p.p.m. However, during the summer, it exhibited a greater variation; in July 1927 it reached a maximum of 17 p.p.m. The two increases in the amount of chlorides in July and September were perhaps due to additions as a result of drainage after heavy rains; or they may have been due to a concentration as a result of evaporation, for the water level fell about 27.5 cm. during the summer, and only a small part of this reduction in level was probably due to seepage through seams in the rock. The minimum, as is the case for the large pool, appeared in March, both in 1927 and 1928, just before the ice melted. In March 1927 there was a decrease of 4 p.p.m. from that of the February value and in 1928 a decrease of 8.5 p.p.m. from the February reading with the minimum value of 6.5 p.p.m. The bottom water showed a slightly higher chloride content during the latter part of the winter and during the summer; after the fall overturn, both surface and bottom had the same concentration.

Silica. Birge and Juday (1911) found a periodicity in the silica content of the water in Wisconsin lakes, correlated with the seasonal variations in diatom numbers. They found that the silica content of the upper waters decreased during the summer due to its utilization by diatoms. The sinking of the dead diatom shells to the lower water and their subsequent decomposition increased the silica content of the lower water during the summer. With the fall overturn the dissolved silica was uniformly distributed from surface to bottom, thus furnishing favorable conditions for the multiplication of diatoms. Pearsall (1923) found that the increased diatom growth was associated with heavy rains in spring and fall which brought dissolved silica and nitrates into bodies of water by drainage.

The amount of dissolved silica in the surface water of the Wauwatosa pool varied from minima of 2.8 p.p.m. in March 1928 and 3.0 p.p.m. in October 1927, to a maximum of 7.5 p.p.m. in February 1928. The bottom water was about 0.5 to 1.5 p.p.m. higher than the surface in silica content before the overturn, but after the overturn in November it had less than the surface. During the winter the silica accumulated in the bottom water until it had about 0.5 p.p.m. more than the surface water. The amount of soluble silica fell in March in a manner similar to the fall in chloride content described above, and may have been due to the same cause.

The amount of silica in the North Milwaukee pool was less than that in the large pool. The surface water was low in soluble silica during the summer, with about 0.7 p.p.m. Both the surface and bottom increased in silica content after the fall rains. The maximum for the surface was reached in November 1927 with 5 p.p.m. During the winter the silica increased in both the surface and bottom waters. The maximum for the bottom was reached in March 1928, with 5.5 p.p.m.

Nitrogen. No definite correlation could be found between the various forms of nitrogen in the pools. In general the various forms of nitrogen tend to run parallel to each other. In the Wauwatosa pool the maximum organic nitrogen was found on October 31, 1927 with 3 p.p.m. A minimum of 0.35 p.p.m. preceded this. The maximum is correlated with a maximum crop of plankton, but the minimum is not so correlated with a minimum crop of plankton. The higher organic nitrogen values seem to be coincident with high counts of entomostraca. The high point of the nitrate curve was the same for both pools and fell on October 31, 1927. It is not due to nitrates brought in by rains for there was no rain for the fortnight preceding this date. The nitrates were low in the summer in the Wauwatosa pool, due to the demand made upon them by the phytoplankton. The ammonia nitrogen was also low during the summer. During the winter the bottom water of the Wauwatosa pool contained from 0.13 to 0.03 p.p.m. of ammonia nitrogen less than the surface, although soon after the overturn in November it had 0.5 p.p.m. more.

A similar condition was found for nitrogen in the North Milwaukee pool. The variations between the surface and bottom were not as great as they were in the Wauwatosa pool. The nitrates were much lower than any of the other forms of nitrogen, and agree with the findings of Domogalla and others for Wisconsin lakes. The nitrites in the Wauwatosa pool varied between 0.0015 and 0.0095 p.p.m. while those for the smaller pool varied between a trace and 0.0195 p.p.m.

Phosphorus. There is a discussion in regard to the role of phosphorus in the economy of plankton growth. The studies of Atkins (1923, '24, '26) and Atkins and Harris (1925) introduced the theory that phosphorus is a limiting factor in the growth of phytoplankton. The whole question is discussed by Juday et al (1927) in a study of lakes of northeastern Wisconsin. They find no correlation between the soluble phosphorus and the phytoplankton, nor do they find any correlation between the amount of centrifuge plankton and the organic phosphorus.

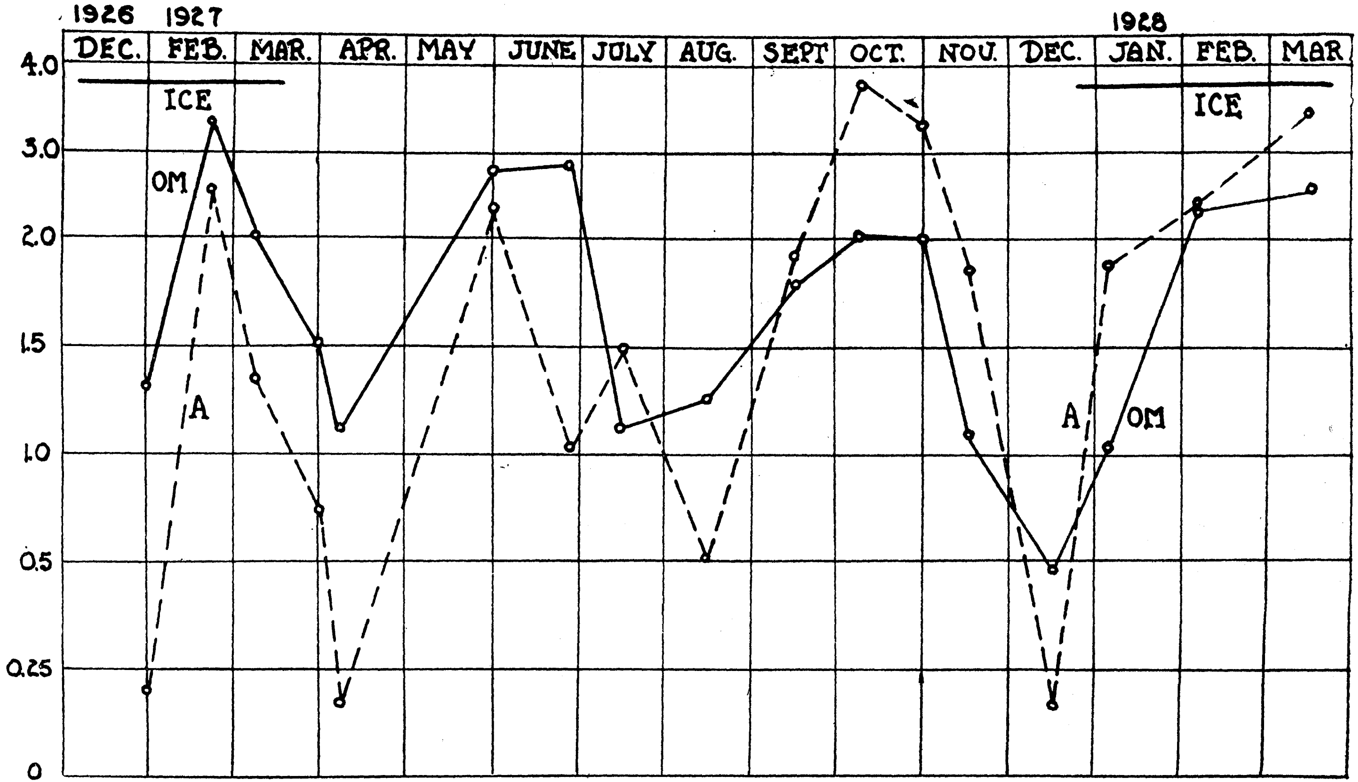

FIG. 4. Organic matter (curve marked OM) and ash (A) of centrifuge plankton of Wauwatosa pool, indicated in milligrams per liter of water.

A similar condition appears to maintain for these pools. The maxima of the soluble phosphorus came in September and February in the large pool when the soluble phosphorus reached 0.12 and 0.14 p.p.m. respectively. The average was generally about 0.03 p.p.m. The bottom water held less soluble phosphorus than the surface and there was no accumulation of it at the bottom during the winter. The organic phosphorus was not correlated with the net plankton or with the centrifuge plankton counts.

The soluble phosphorus in the North Milwaukee pool was lower than that of the Wauwatosa pool. Its average was about 0.003 p.p.m. and the highest points were found in September and January when 0.08 and 0.06 p.p.m., respectively, were reached. Here, again, except for the high peak in the curve in March 1928, there was no correlation between the organic phosphorus and the plankton. In March 1928 there was a coincident rise in the nannoplankton.

Organic matter. A study of the volatile or organic matter obtained by ashing the centrifuge plankton shows this to correspond very well with the net plankton counts as well as with the counts of the centrifuge plankton. (Fig. 4) The Wauwatosa pool had a maximum of organic matter in February 1927 with 3.32 mg. per liter. February 1928 showed 2.43 mg. per liter of organic matter present. The minima came in April and July, 1927 with slightly more than 1.1 mg. of organic matter per liter. The influence of diatoms as the dominant portion of the plankton crop is seen by the increase in ash at such times.

The North Milwaukee pool, except for July 1927 with a minimum of 0.75 mg. of organic matter per liter, showed higher values than the large pool. This was due to the greater abundance of plankton in the small pool. Here, too, the organic matter followed the trend of the curve for the plankton. The curve also shows the two annual maxima, the one in spring, and the other in the fall. (Fig. 5).

PLANKTON

In addition to the physical and chemical factors, there are the complex interrelations between the various inhabitants of the pools. The Wauwatosa pool had a deficiency and at times a complete lack of oxygen in the lower levels, while the North Milwaukee pool was well supplied throughout its depth at all times. Atkins and Harris (1924) found that bodies of water with the bottom waters low in oxygen, have diatoms and Peridinieae, while those with a plentiful supply at all times support Chlorophyceae and Protoccales, primarily. Pearsall (1921, 1922) found that, in bodies of water where the value of the ratio Na

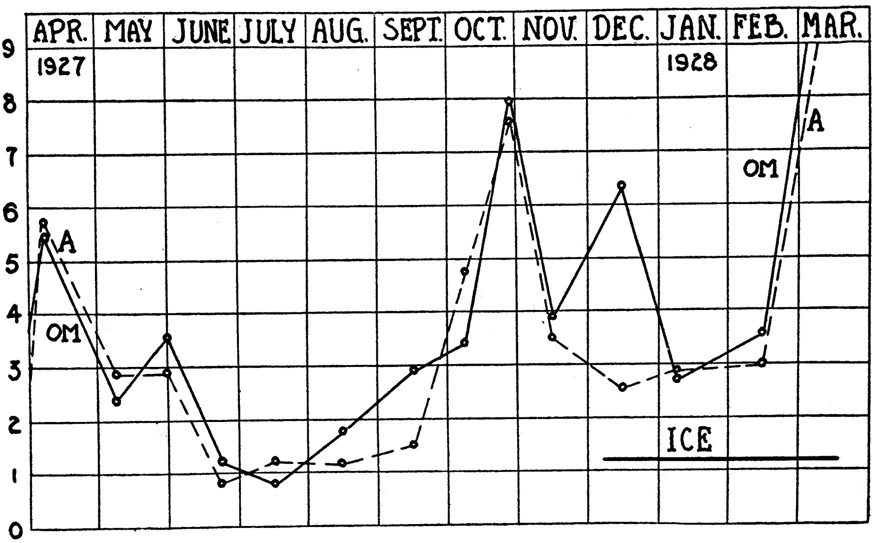

Fig. 5. Organic matter (curve marked OM) and ash (A) of centrifuge plankton of North Milwaukee pool, indicated in milligrams per liter of water.

and K to Ca and Mg was high, a desmid flora predominated, while a diatom flora predominated in bodies of water with a low ratio and where the silica and nitrates were present in sufficient quantities.

The Wauwatosa pool had low oxygen in the bottom water and had a predominant diatom and dinoflagellate plankton. Both pools had a large amount of Ca and Mg, consequently a low value for the Na and K ratio, and the diatoms predominated at certain seasons of the year. In the North Milwaukee pool, with oxygen at all levels at all times, the Chlorophyceae predominated during the summer.

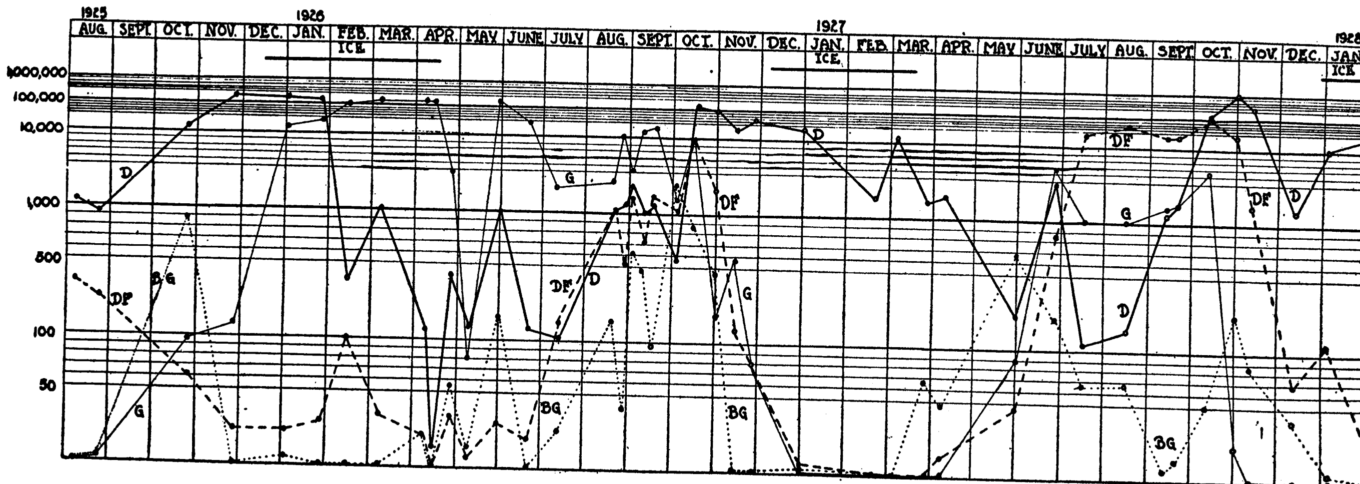

FIG. 6. Diagram showing the number of individuals and colonies in the net phytoplankton of the upper meter of water in the Wauwatosa pool. D—diatoms; G—green algae; BG—blue green algae; DF—dinoflagellates.

In the Wauwatosa pool the diatoms were abundant in spring and fall, with the latter as the greater of the maxima. (Fig. 6). The growth of diatoms begins in the late summer and the maximum is reached in October or November. Two genera are dominant, one succeeding the other. Fragilaria appeared first and was followed by Asterionella in greater numbers, which continued to be dominant for varying periods, often into March. The maximum of diatoms was reached on October 31, 1927 with 1,000,000 colonies of Asterionella per liter in the net plankton. In the early months of 1926 Eudorina became the dmoinant plankton organism, and continued so through April, reaching a maximum of 250,000 colonies in March. This was its only appearance in numbers in the pool during the time it was studied. After the decrease in the number of Eudorina, Sphaerocystis began to appear and increased in numbers, overshadowing the diatoms in the spring. During the latter part of summer Oocystis took the place of Sphaerocystis and reached its maximum number in September with 40,000 colonies and individuals per liter. In October this organism was surpassed in numbers by diatoms again. In 1926, Ceratium, which is dominant in early fall, did not reach as great numbers as it did in 1927. During the summer of 1927 there was a very meager plankton population. In the latter part of the summer the dinoflagellates became the dominant organisms, with two pronounced peaks in their numbers. The first peak came in August with 70,000 cells per liter and the maximum came in October, just before encystment, with 100,000 individuals, chiefly Ceratium. Peridinium numbered a few hundred cells per liter. After the cool weather of the second week of October, Ceratium decreased in numbers and began to encyst. On October 31, 1927 the cysts numbered 1,000 per liter as compared to 30,000 encysting individuals.

At this time, also, several cases of abnormalities in the number of horns or spines of Ceratium were found, similar to those described by Huber-Pestalozzi (1927). These abnormalities consisted of unusual twistings of the spines, especially one or more of the spines of the hypovalve. In about ten cases, seen in the course of the plankton counts, a doubling of one or more of the hypovalve spines was ob-

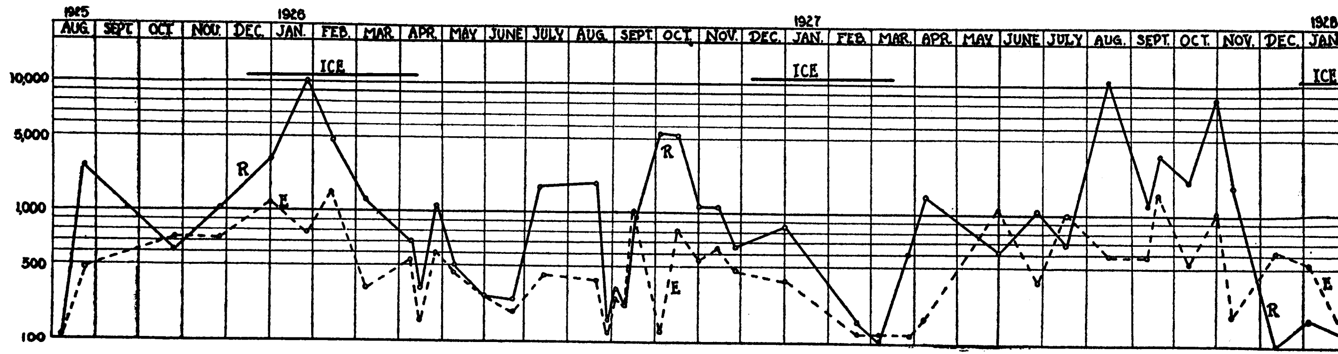

FIG. 7. **Diagram showing the number of rotifers (R) and entomostraca (E) in the net plankton of the upper meter of water in the Wauwatosa pool.**

served, similar to that shown in fig. II (No. 8) of Huber-Pestalozzi's paper. In one case each of the three hypovalve spines was duplicated and in another, two extra spines were present. In each case the spines were well developed and not mere stumps.

Among the less abundant forms, the blue greens reached their highest numbers in October, May and June. In the fall, the common ones were Oscillatoria and Anabaena, while in the spring and early summer Chroococcus was most common.

The rotifers were abundant in the late summer. At this time Polyarthra was the most common rotifer. In 1926 the maximum occurred in January, with 1,000 per liter consisting of almost equal numbers of Polyarthra and Anuraea. In 1927 the maximum came in August, with 1,600 per liter, the most common being Polyarthra. (Fig. 7).

The entomostraca were found in greatest numbers in the fall, although there were a few exceptions to this; small increases were found during the summer. Since the seasonal variations were studied primarily in the upper meter of water, where the entomostraca are rarely found in great numbers, the curve for them may be somewhat misleading. The greater part of the entomostraca in the upper meter of water consisted of nauplii. There seemed to be no definite cycle in the numbers of the nauplii. This is also the condition found by Birge and Juday (1922). Daphnia, Cyclops, and Diaptomus were the most common of the entomostraca. These forms show a diurnal migration. (Juday 1904). In samples of water collected during the day, Daphnia and Diaptomus were most abundant between two and four meters, where at times 50 Daphnias and over 100 Diaptomi per liter were present. On July 15, 1927 samples were taken at the surface at 9:00, 9:30, 10.00, and 11:00 p. m. An almost full moon rose at 10:00 p. m. At 9:30 the surface water yielded the greatest number of entomostraca—about 200 Diaptomus and 75 Cyclops. Daphnia were present in very small numbers—1 adult and 11 young individuals. The following noon another sample was taken and no entomostraca, other than several nauplii were present. (Fig. 7).

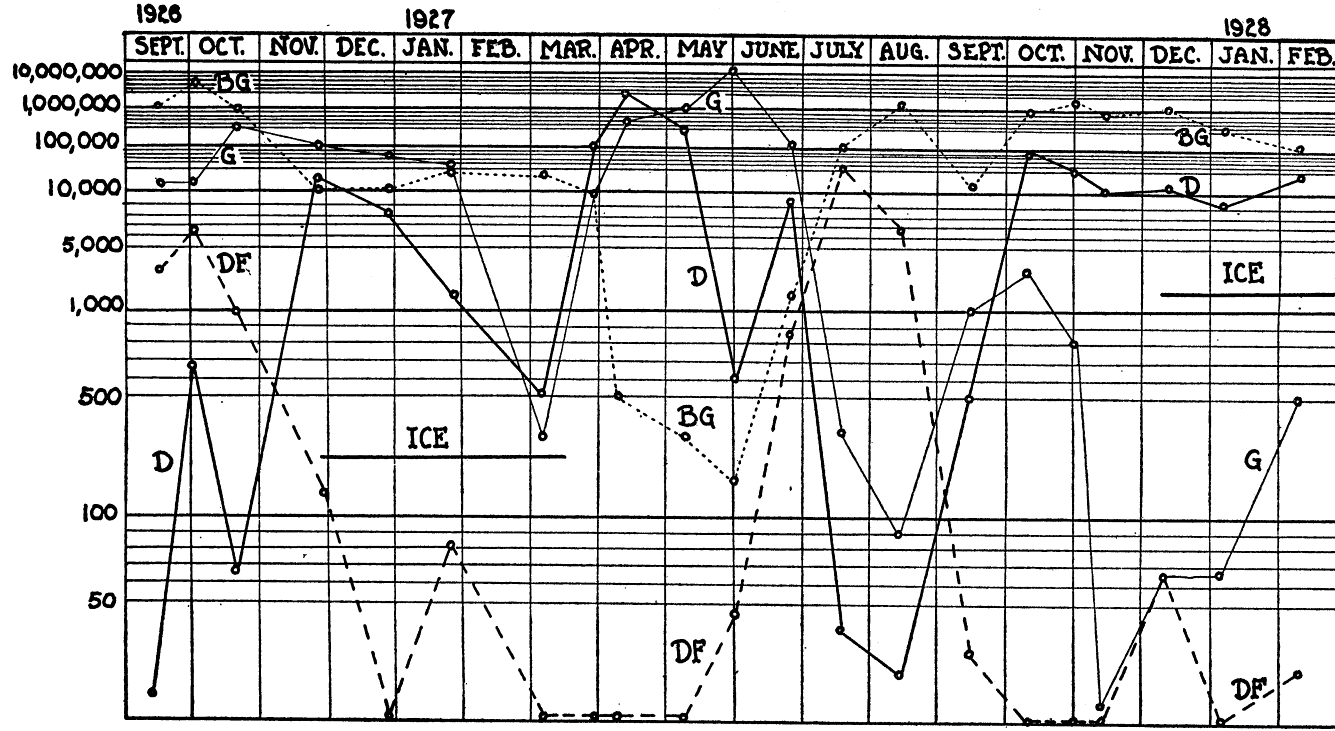

Fig. 8. Diagram showing the number of individuals and colonies in the net phytoplankton of the upper meter of water in the North Milwaukee pool. D—diatoms; G—green algae; BG—blue green algae; DF—dinoflagellates.

The North Milwaukee pool shows a much greater wealth of organisms. The number varies between 40,000 and over 29,000,000 per liter in the net plankton. The maximum growth of plankton came in the spring instead of in the fall as was the case for the Wauwatosa pool. The dominant forms were different from those in the large pool.

The diatoms were not the dominant plankton forms, except early in the spring, when Synedra and Diatoma were most abundant for a short time. In the late summer and fall the blue greens (Aphanizomenon and Anabaena) were the most common organisms. In the fall of 1926, Synura was next to the blue greens in numbers, reaching a total of 500,000 colonies per liter in October. Synura did not appear in the fall of 1927, leaving the diatoms second in number of individuals. (Fig. 8).

Toward the early part of the winter of 1926 Synura gave way to a crop of Dinobryon of which, in January 1927, there were 50,000 colonies of about 20 cells each. The number of Dinobryon then decreased, but in May rose again, and then were completely overshadowed by a heavy crop of monads which in the net plankton numbered 29,000,000 per liter.

The dinoflagellates were not as conspicuous in the North Milwaukee pool because other forms were more numerous. The greatest number was found in July 1927 when 65,000 Ceratium and 2,000 Peridinium per liter of water were present. The Ceratium in this pool was larger and broader, with heavier spines than that in the Wauwatosa pool. This form was followed in August by a slender and smaller type, often with only two spines on the hypovalve.

The protozoa were more abundant in the smaller pool than in the larger one. In October 1926 the protozoa reached the highest point, with over 60,000 cells per liter. The greatest number of them consisted of Codonella, although free swimming Vorticellas of several species numbered over 2,000 per liter. In 1927 the crop of protozoa was not as large, amounting to 2,000 per liter. The protozoa were most numerous in October and March with a slight rise in numbers also in June.

The rotifers also were more numerous than in the Wauwatosa pool, reaching a maximum of over 50,000 per liter

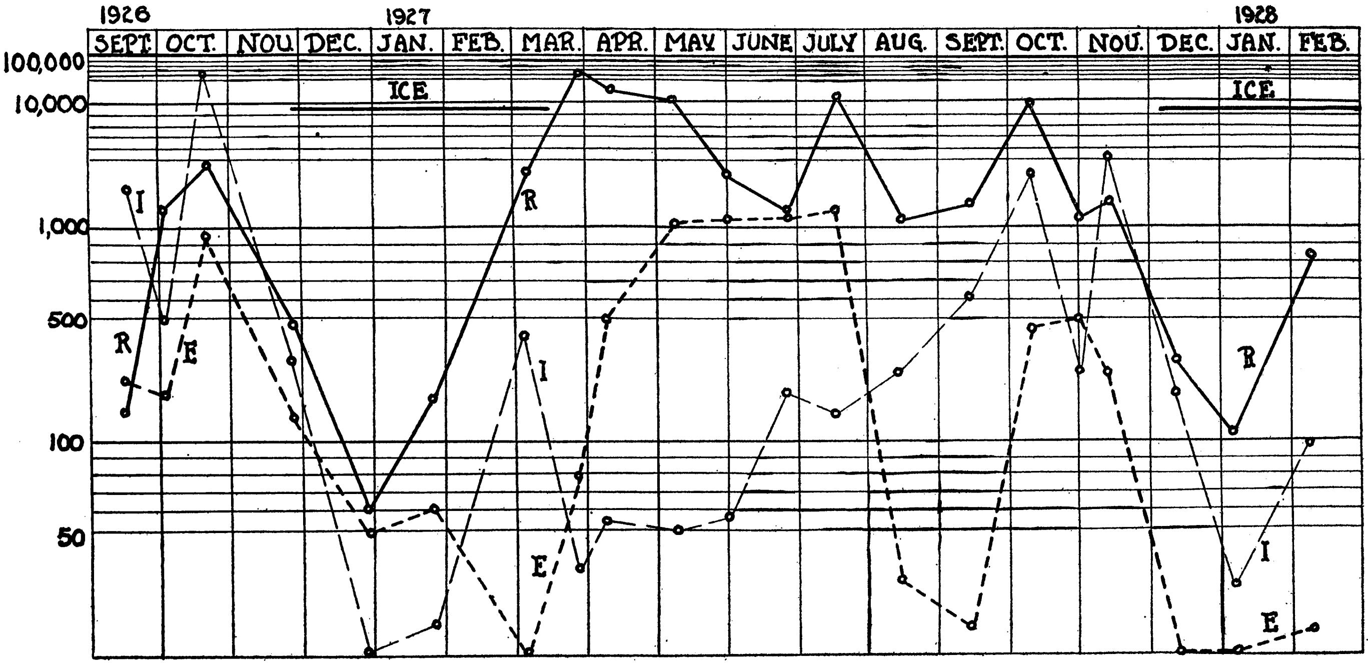

FIG. 9. **Diagram showing the number of infusoria (I), rotifers (R) and entomostraca (E) in the upper meter of water in the North Milwaukee pool.**

on March 27, 1927. This is about thirty times the maximum number found in the large pool. This maximum consisted mainly of Polyarthra (22,000), *Anuraea aculeaea* (20,000), *A. cochlearis* (6,000) and Triarthra (2,000). A second peak in the rotifers was found in July, when they numbered 25,000 per liter with *A. cochlearis* as the common form. In October 1927 a third peak was found when they reached 14,000 per liter with *A. cochlearis* var. *tecta* most common. (Fig. 9).

The entomostraca were represented by Cyclops, primarily, and nauplii formed the greatest contribution to their number. The maxima were found in late fall, late spring and early summer. The following table will give some idea of the numbers of entomostraca in the surface water at the periods of greatest abundance.

	Oct. 1926	*May* 1927	*July* 1927
Diaptomus	50 per liter	600	60
Cyclops	700	100	60
Nauplii	200	500	1200
Daphnia	25	—	35
Bosmina	80	100	700

This study of the plankton of the two pools shows that they are very different with respect to the kinds and the numbers of organisms they maintain. The increase in phytoplankton does not seem at all times to be due to the increase in the intensity of light in the spring, for at times some phytoplankton organisms reach their maximum when the light conditions are poor, (Eudorina in the Wauwatosa pool in March). In the North Milwaukee pool there is an increase in the number of phytoplankton organisms in the spring and this appears to be due in part to the increase in actinic power of the light at this time as suggested by Lloyd (1926). The greatest growth of diatoms takes place when the water is between 10° and 15°C. and at a time when the light is not too intense. (Whipple, 1927). In general, the protozoa occur in greatest numbers when certain of the phytoplankton forms are most numerous, and similar relations seem to hold between the rotifers and entomostraca. Of the Cyanophyceae, Aphanizomenon is more tolerant of a wide range of temperature than most algae, Whipple (1927). It occurred in greatest numbers when the temperature of the water was near its highest point (24°) in August, and persisted throughout the fall and winter, in December reaching as many as 1,000,000 filaments per liter under the ice. In fact, the growth of Aphanizomenon was so heavy that the ice became greenish and was not harvested because of the discoloration. Whipple (1927) cites a similar case.

At various times, samples were taken at different stations to study the horizontal distribution of the plankton. Although some small variations were found at times, they were not of sufficient magnitude to enable one to draw conclusions. With very little wind, the plankton organisms probably had a fairly uniform horizontal distribution. Whipple (1927) believes that the horizontal distribution is quite uniform.

The vertical distribution is, to a certain extent, dependent upon the wind. Some of the diatoms tend to sink in quiet water, while a circulation of the water by the wind will keep them in the upper stratum. Aphanizomenon tends to float on the surface of the water, but a wind would carry some down to the lower water. (Whipple 1927). The vertical distribution in the North Milwaukee pool was fairly uniform. The greatest growth was found within the upper meter. The greatest number of organisms may be found in either the first or the second half-meter of water. From one meter downward, there was a gradual diminution in numbers, with the smallest number at the bottom. In the Wauwatosa pool uniform distribution was noted only when the temperature was uniform and the water was in full circulation. When stratification was pronounced there was an abrupt change in the number of plankton organisms at different levels. As in the North Milwaukee pool, the greatest number of organisms was found in the first meter of water, except for the entomostraca as noted above.

The nauplii were most abundant at the surface, while Diaptomus and Cyclops were most common in the second half-meter of water. Daphnia were most abundant between two and four meters. Of the rest of the forms there was a gradual decrease toward the bottom. When stratification is present there is no such gradual fall in numbers from the surface to the bottom. At such times the entomostraca were still found in greatest numbers between two and five meters, the nauplii and Cyclops at higher levels than the Daphnia.

Table 1 gives the numbers of the various organisms at the different levels of the two pools during the four important seasonal periods of the year. The first column in May, shows the vertical distribution when the temperature is almost the same from surface to bottom, during the period of the spring overturn in the Wauwatosa pool. The summer period of stagnation and stratification is seen in the column for August. The fall period of uniform temperature and overturn comes in November, while the winter condition is seen in February.

Summary

1. Physical, chemical and biological observations were made on two limestone quarry pools in the vicinity of Milwaukee, Wisconsin.

2. The temperature of the surface water of the two pools followed that of the air in a general way, rising somewhat more rapidly in the spring and falling more slowly in the autumn. The Wauwatosa pool was thermally stratified during the summer. With a maximum depth of only 5 m., the North Milwaukee pool was substantially uniform in temperature from surface to bottom.

3. The North Milwaukee pool contained an abundance of oxygen at all depths throughout the year; dissolved oxygen entirely disappeared from the bottom water of the other pool in summer and in winter. There was no definite correlation between the various forms of nitrogen in the two pools; in general there was a correlation between the organic nitrogen and the plankton crop. Nitrates were low in summer. No correlation was found between the phosphorus and the plankton.

4. Diatoms and dinoflagellates were dominant in the Wauwatosa pool, and Chlorophyceae and Cyanophyceae in the North Milwaukee pool. The latter pool had a greater number of plankton organisms per liter and also a greater

variety of species. The maximum crop of plankton was found in the spring in the North Milwaukee pool, but it came in the fall in the Wauwatosa pool. Protozoa and rotifers were more abundant in the North Milwaukee pool than in the Wauwatosa pool. With the exception of the entomostraca, the largest number of plankton organisms was found in the upper meter of water in both pools. The vertical distribution of the summer plankton in the Wauwatosa pool was similar to that of stratified lakes.

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Table 1. *Summary of the vertical distribution of the various plankton organisms in the two pools. The results are stated in the average number of individuals per liter between the depths given.*

Plankton	Depth	Wauwatosa Pool				North Milwaukee Pool			
		May 29, 1927	Aug. 11, 1927	Nov. 11, 1927	Feb. 4, 1928	May 31, 1927	Aug. 14, 1927	Nov. 12, 1927	Feb. 5, 1928
Entomostraca	0–½	156	44	—	—	1,178	16	270	—
	½–1	100	78	33	—	1,611	22	324	22
	1–2	66	50	50	5	517	72	111	11
	2–3	35	61	83		288	806	129	—
	3–4	91	38	44	15	452	—	100	5
	4–5	—	39	66	—	55	289	—	16
	5–10	—	11	13	7	—	—	—	—
	10–15	—	5	7	9	—	—	—	—
	15–20	—	1	—	7	—	—	—	—
Rotifera	½	67	1,875	346	11	4,018	5,304	3,580	1,218
	1	55	1,532	135	—	3,885	2,104	1,789	391
	2	41	1,072	56	2	1,151	627	675	245
	3	16	335	78	—	1,035	252	535	993
	4	11	117	11	5	1,052	1,121	483	507
	5	—	16	28	—	1,732	—	—	375
	10	—	5	6	1	—	—	—	—
	15	—	8	1	—	—	—	—	—
	20	—	1	—	—	—	—	—	—
Protozoa	½	—	1,141	33	—	11	884	9,217	89
	1	—	1,126	—	—	100	134	2,676	111
	2	—	313	—	2	6,216	837	1,027	27
	3	—	28	5	—	5,580	694	954	189
	4	5	22	—	—	2,374	291	763	79
	5	—	11	—	—	542	—	—	66
	10	—	1	1	—	—	—	—	—
	15								
	20	—	—	4	—	—	—	—	—
Total Zooplankton	½	223	3,060	379	11	5,207	6,204	13,067	1,307
	1	155	2,736	168	—	5,596	2,260	4,718	524
	2	107	1,435	106	9	7,884	1,536	1,813	283
	3	51	424	166		6,903	1,752	1,618	1,182

TABLE 1. *Summary of the vertical distribution of the various plankton organisms in the two pools. The results are stated in the average number of individuals per liter between the depths given*—Continued.

Plankton	Depth	Wauwatosa Pool				North Milwaukee Pool			
		May 29, 1927	Aug. 11, 1927	Nov. 11, 1927	Feb. 4, 1928	May 31, 1927	Aug. 14, 1927	Nov. 12, 1927	Feb. 5, 1928
Total Zooplankton—Continued	4	102	177	55	20	3,878	1,701	1,346	589
	5	—	66	94	—	2,329	—	—	457
	10	—	17	20	8	—	—	—	—
	15	—	13	8	9	—	—	—	—
	20		2	4	7	—	—	—	—
Blue Greens	½	884	89	—	—	235	2,100,616	1,322,484	353,600
	1	420	44	179	—	189	3,200,626	678,470	153,680
	2	621	44	44	—	8,924	1,361,830	758,554	60,112
	3	610	11	16	—	7,477	142,386	690,360	110,922
	4	627	—	33	—	224	309,724	528,688	134,368
	5	—	5	44	—	22	—	—	89,708
	10	—	—	10	—	—	—	—	—
	15	—	—	1	—	—	—	—	—
	20	—	—	14	—	—	—	—	—
Diatoms	½	224	111	919,449	61,243	648	11	21,700	76,136
	1	267	268	235,222	48,841	492	11	21,758	30,020
	2	83	116	146,055	36,378	167	—	11,178	7,698
	3	228	93	99,946	—	212	—	20,445	19,150
	4	395	56	81,826	32,818	30	—	25,142	5,332
	5	—	33	154,800	—	246	—	—	7,100
	10	—	5	104,795	26,607	—	—	—	—
	15	—	3	42,293	19,654	—	—	—	—
	20	—	—	77,888	21,087	—	—	—	—
Greens	½	99	—	—	—	30,744,620	44	—	671
	1	133	—	—	—	28,747,847	—	11	380
	2	71	—	—	5	9,835,898	99	11	21
	3	110	5	11	—	6,632,239	167	5	—
	4	38	16	—	5	1,805,846	—	8	44
	5	—	—	—	—	1,076,666	—	—	33
	10	—	—	1	—	—	—	—	—
	15	—	—	—	—	—	—	—	—
	20	—	—	18	—	—	—	—	—

Table 1. *Summary of the vertical distribution of the various plankton organisms in the two pools. The results are stated in the average number of individuals per liter between the depths given*—Continued.

Plankton	Depth	Wauwatosa Pool				North Milwaukee Pool			
		May 29, 1927	Aug. 11, 1927	Nov. 11, 1927	Feb. 4, 1928	May 31, 1927	Aug. 14, 1927	Nov. 12, 1927	Feb. 5, 1928
Dinoflagellates	½	67	97,240	4,061	11	22	27,404	------	44
	1	22	53,924	996	33	66	7,850	------	------
	2	------	28,735	1,127	102	39	5,357	------	------
	3	11	8,840	482	------	11	5,000	------	------
	4	21	9,293	234	38	------	4,502	------	------
	5	------	1,500	296	------	------	------	------	------
	10	------	286	171	57	------	------	------	------
	15	------	11	44	30	------	------	------	------
	20	------	25	30	6	------	------	------	------
Total Phytoplankton	½	1,274	97,440	923,510	61,254	30,745,525	2,128,075	1,344,184	430,451
	1	842	54,236	236,397	48,874	28,748,594	3,208,487	700,239	184,080
	2	775	28,895	147,226	36,485	9,845,028	1,367,286	769,743	67,831
	3	959	8,949	100,455	------	6,639,939	147,553	710,810	130,072
	4	1,081	9,365	82,093	------	1,806,700	314,226	553,868	139,744
	5	------	1,538	155,140	32,861	1,776,934	------	------	96,841
	10	------	291	104,977	26,664	------	------	------	------
	15	------	14	42,338	19,684	------	------	------	------
	20	------	25	77,950	21,093	------	------	------	------
Temperatures	½	12.2°C.	22.3°	11.5°	5.0°	12.7°	24.0°	7.4°	1.2°
	1	12.2	22.0	11.0	5.1	12.5	23.0	7.4	2.0
	2	12.2	22.0	10.7	5.1	12.5	19.0	7.4	------
	3	12.2	20.0	10.7	5.2	12.5	------	7.4	3.2
	4	10.0	16.0	10.6	5.2	11.5	18.0	7.4	------
	5	8.2	14.5	10.6	5.2	10.2	17.0	7.4	5.0
	10	------	14.5	10.6	5.2	------	------	------	------
	15	------	14.5	10.6	5.2	------	------	------	------
	20	------	14.5	10.6	4.9	------	------	------	------

THE MORPHOLOGY AND DEVELOPMENTAL STAGES OF A NEW SPECIES OF PIONA

RUTH MARSHALL

The material for this study was found by Dr. J. R. Hickman while collecting bottom forms for the Wisconsin Geological and Natural History Survey. The author is also indebted to Dr. E. A. Birge and Professor Chancey Juday for permission to examine the water mites collected during the summer of 1928 at the Trout Lake Laboratories.

On August 4, a large number of nymphs of a Piona were found on branches of Nitella taken from Lake Kawaguesaga near Minocqua. Some of this material was kept under observation for the next ten days; similar material was later found in other lakes of the region. On the day they were discovered, the nymphs appeared passive, with legs outstretched and heads resting on the plant stems. The body at this stage is rotund, with a yellow dorsal streak; the epimera are small and well separated. The genital plates are obliquely set and each bears two round acetabula (fig. 7). In the water about these nymphs were found great numbers of newly emerged males and they continued to be abundant for several days, together with a few specimens of *Hygrobates longipalpis*. Very few females were seen at first; but three days later they, too, were abundant. Copulating pairs then appeared and a few first larvae.

Pairing as observed here agrees with accounts given for other species of this genus and illustrates the use of the peculiarly modified legs of the male. The female remains passive with legs outstretched. The male rests on the anterior end of the ventral side of the female with the fourth legs flexed so that the concavities of the fourth segments are hooked over the first legs of the female. The club-shaped distal segments of the third legs, which are usually seen held together on the genital orifice, now transfer the semen masses to the genital opening of the female. The entire process lasts but a few moments, when the pair separate.

On August 8, egg masses were observed on the plant stems (fig. 9). Each mass was about 2.5 mm. in length and contained from twenty to thirty pale, oblong eggs placed irregularly in a transparent jelly. Larvae were emerging until August 14, at which time all of the second larvae had apparently pupated and young females were abundant. Material from Little Arbor Vitae Lake collected August 27 consisted chiefly of nymph cases and young males. The first, or six-legged larva is a very delicate, active creature, measuring 0.475 mm. to the tip of the capitulum (fig. 8). The body is broad, pale brown with a pale blue area dorsally near the anterior end. The epimera cover most of the ventral side, as in other recorded larvae of the genus; the surface is covered with fine oblong hexagonal areas. The posterior end of the body bears two papillae and numerous long hairs. The subsequent history of these larvae is not known; in other species they are believed to attach themselves to the bodies of small water beetles soon after hatching.

The newly emerged adults are very delicate and transparent, with a pale yellow to reddish Y-shaped dorsal mark. The males are about 0.975 mm. in length; the females of the same period are at first smaller, but soon exceed them in size. The epimera now occupy much of the ventral surface; the second pair have well developed anchoral processes, the fourth pair are very large (fig. 1). The genital areas are about half enclosed by the deep bay formed by the concave margins of the last epimera, those of the male barely joining them in the mid-line. The orifice in the male is broadly trifoliate and large; in the female there is a long slit. The genital plates are large, oval and similar in the two sexes, with about thirty acetabula on each, the latter variable in size and arrangement, with two on each plate larger than the others (fig. 3, 4).

The maxillar shield is large and broad. The palpi exceed the legs in width and bear few bristles; the fourth segment is slim, with one large and two smaller anteriorly directed papillae on the flexor surface with still another near the distal end. The fifth segment is curved and ends in four finger-like processes (fig. 6). The legs are long and well provided with bristles and swimming hairs. In the male the third leg has a club-shaped distal segment with a claw transformed into a long delicate hook (fig. 4); the fourth segment of the last leg has a conspicuous concavity bordered by rows of blade-like hairs (fig. 5).

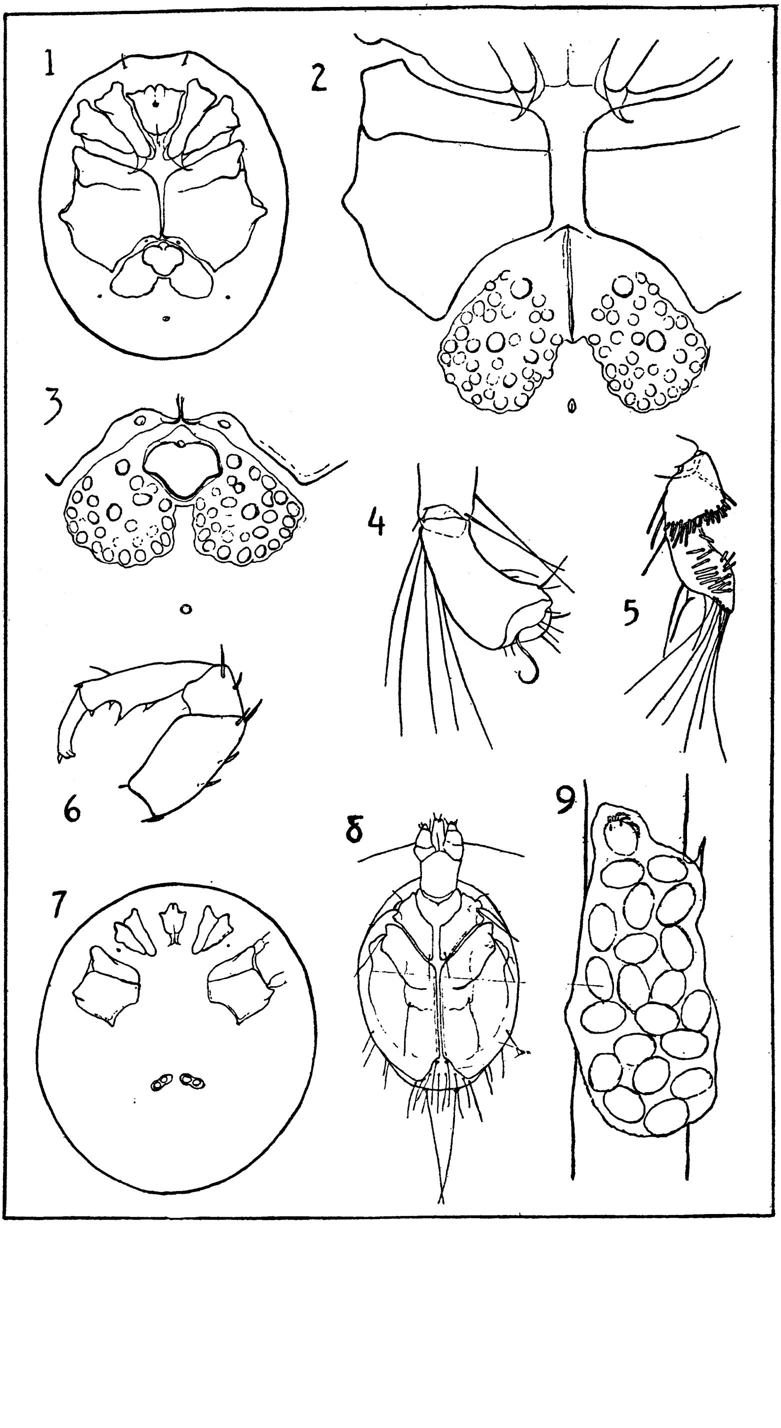
The species appears to be a new one, probably widely distributed in this country and will be named *Piona americana* nov. spec. It bears some resemblance to *P. turgida* (Wol.), a larger species with which it was at first confused. It is closely related to *P. coccinea* (Koch), which, together with its varieties, is widely distributed in Europe and reported also from parts of Asia and Africa. The two species are very similar in the form of the genital orifices and the third and fourth legs of the male, but differ in details of structure.

Biological Laboratory,
Rockford College,
Jan. 1, 1929.

EXPLANATION OF PLATE 9

Piona americana

FIG. 1. Ventral view, male.
FIG. 2. Genital area and epimera, female.
FIG. 3. Genital area,male.
FIG. 4. Sixth segment, third leg, male.
FIG. 5. Fourth segment, fourth leg, male.
FIG. 6. Left palpus.
FIG. 7. Ventral surface, 2nd larva.
FIG. 8. Ventral surface, 1st larva.
FIG. 9. Egg mass on stem of Nitella.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A PRELIMINARY LIST OF THE MOLLUSCA OF DANE COUNTY, WISCONSIN

J. P. E. MORRISON

INTRODUCTION

The purpose of the following paper is to tabulate the distribution of the molluscs of this region, as far as known at the present time. It is intended as a checklist, with locality records, of this particular portion of the fauna of the area surrounding Madison. For convenience, the boundaries of the county have been taken as the limits of the area. The Wisconsin River, the northwest boundary of the region, has been included in the survey.

In the preparation of the list, material has been taken from three sources, namely: (1) published lists, including scattered references, where found. (2) the collections in the Museum of the University of Wisconsin. (3) collections made by the writer in the area under consideration.

Acknowledgements are due the following people, who have aided the work in various ways: Frank C. Baker, University of Illinois, Mr. Chancey Juday, and Mr. Geo. Wagner, University of Wisconsin. To Mr. Wm. J. Clench, Harvard Museum of Comparative Zoology, for determination of the Physidae; Dr. Victor Sterki, New Philadelphia, Ohio, for determination of the Sphaeriidae; Dr. Bryant Walker, Detroit, Michigan, are due many thanks for their kind cooperation. Unfortunately, all of the Ancylidae in the author's personal collections from the vicinity of Madison have recently been lost in the mails. As they had not yet been examined by Dr. Walker, the records are unavailable specifically, and not included.

I wish also to thank the many friends who have aided in the field, by assistance in collecting, especially: Mr. Orlando Park, of the University of Chicago; Mr. Ralph Bailey, Mr. L. G. Gumbreck, Mr. J. H. Roberts, of the University of Wisconsin; Mr. Chatt Himley, of Madison.

In 1823, Mr. D. H. Barnes, of New York, published an article in the American Journal of Science, describing some new species of Fresh Water Mussels. The specimens he described were received by him from Capt. D. B. Douglass, topographical engineer, and Mr. H. R. Schoolcraft, mineralogist, of the N. W. Expedition. The records are the first from this region.

Mr. I. A. Lapham, of Milwaukee, was probably the first Wisconsin man to make careful studies of the molluscan fauna of the State. In 1852, he published a catalogue of the fauna, both recent and fossil, and of the flora known at that time from Wisconsin. Included in the list were some ninety forms of mollusks. Again in 1860, he published a list of the shells of the State. This second list, published in an eastern journal, was an abridged copy of the first one, and did not contribute more to our knowledge of the fauna. However, Mr. Lapham's original list is an invaluable record of its kind.

Likewise among the early records from Dane County are those of Prof. Spencer F. Baird, who was the first curator of the Smithsonian Institution. In the summer of 1853, he visited Dr. P. R. Hoy, of Racine, doing quite a bit of natural history work with him during the summer. On July second, they set out, together with Dr. J. P. Kirtland, on a longer excursion through southern Wisconsin. This trip included a stop at Madison, where most of their collecting was done in the neighborhood of Gov. Farwell's Mills, located at the foot of Lake Mendota, between that lake and Lake Monona. Baird's records were published in Binney's monographs of 1865.

Between the years 1887 and 1899, Geo. Marston collected extensively in eastern Wisconsin, including many collections from the Wisconsin River.

In 1897, Mrs. E. C. Wiswall published a list of shells of Southern Wisconsin. Some few of these records are referable to Dane County.

In the first decade of the present century, notably in 1904, Mr. Geo. Wagner collected from the lakes around Madison, principally from Lake Mendota.

Incidental to reporting the occurrence of the element manganese in Fresh Water Mussels, Bradley (1910) mentions the two common mussels of the lakes near Madison. He reports them as Anodonta—"the typical lake form," and Unio—(evidently Lampsilis, from the locality mentioned). The writer has taken the liberty of referring these records to the species to which they undoubtedly belong.

The records added by W. H. Dudley, who collected on the Wisconsin River, etc., during the summer of 1918, have been included wherever possible.

Muttkowski, working on Lake Mendota during the period between 1913 and 1916, published on the fauna of the lake (1918). He lists several species that were studied quantitatively, and mentions the fact that there were others in the lake.

Perhaps the records based on the collections of D. S. Bullock, now in the Museum of the University, have added most among previous ones to our knowledge of the kinds of molluscs in the county.

Mr. Frank C. Baker, working in connection with the Geological and Natural History Survey, made extensive collections in the State during the summers of 1920-22. Some of these records are included, where they support records from localities actually within Dane County. Not a small number of records have been taken directly from Baker's monograph (Published in December 1928) but only those have been included that seem unquestionably referable to the area under consideration.

Juday (1922) records *Pisidium idahoense* from the deeper waters of Lake Mendota. It should perhaps be mentioned here that in these studies he carried on, he was dealing with not only the species mentioned, but also with at least three others in addition (in all probability). In his report, all of the pisidia mentioned as of the large class (having a length of 7 mm. or more) were undoubtedly *idahoense*, together with some young specimens listed in the other classes. On the other hand, the great majority of the pisidia mentioned (3,343 recorded as small; that is, as having a length of from 1.5 to 3.5 mm.) were undoubtedly not the above species, but of an undescribed species, in large part. This statement is based on subsequent collections by the writer. Since there is more than one species in the deeper waters of Lake Mendota, Juday's remarks as to the high rate of mortality of the pisidia have become untenable. In substitution, it may be stated that *P. idahoense* is much less common in Lake Mendota than this undescribed species, which is usually no longer than 4 mm.

Finally, during the periods between September 1927 and June 1928, and between September and December 1928, the writer has made collections of molluscs from as many localities and over as great a seasonal range as has been possible in the limited time at his disposal. Besides adding a few species to those previously known from the area, these records have confirmed, in large part, those of the other workers. There are, in the author's collections from the region, some lots of species as yet undescribed. It has been thought best to omit them entirely from the list, in order to avoid any possibility of confusion.

For a full list of bibliographical references, the reader is referred to Baker's Monograph (1928, b.). The following few references will serve as an introduction to the molluscs in the county, including, as they do, the published records from this area.

Baker, F. C. 1902. The Mollusca of the Chicago area. part 2, The Gastropoda. Bull. 3, part 2, Nat. Hist. Sur., Chicago Acad. Sci.

—— 1928.b. The fresh water Mollusca of Wisconsin. part 1, Gastropoda. (Bull. 70. part 1. Wis. Geol. & Nat. Hist. Sur.). Mon. Aquatic Gastropoda of Wisconsin. Wis. Acad. Sci. Art. Let.

—— 1928.b. The fresh water Mollusca of Wisconsin. part 2, Pelecypoda. (Bull. 70. part 2. Wis. Geol. & Nat. Hist. Sur.). Bull. U. of Wis. serial No. 1527, general series No. 1301.

Binney, W. G., and Bland, T. 1869. Land and fresh water shells of North America. part 1, Pulmonata Geophila. Smith. Misc. Coll. No. 194.

Binney, W. G. 1865.a. Land and fresh water shells of North America. part 2, Pulmonata, Limnophila and Thalassophila. Smith Misc. Coll. No. 143.

—— 1865.b. Land and fresh water shells of North America. part 3, Ampullariidae, Valvatidae, etc. Smith Misc. Coll. No. 144.

Bradley, H. C. 1910. Manganese of the tissues of lower animals. Jour. Biol. Chem. 8:237–249.

Chadwick, G. H. 1906. Notes on Wisconsin Mollusca. Bull. Wis. Nat. Hist. Soc. 4:67–99.

Juday, C. 1922. Quantitative studies of the bottom fauna in the deeper waters of Lake Mendota. Trans. Wis. Acad. Sci. Art. Let. 20:461–493.

Lapham, I. A. 1852. Catalogue of the Mollusca of Wisconsin. Trans. Wis. State Agric. Soc. 2:367–370.

—— 1860. A list of the shells of the State of Wisconsin. Proc. Phila. Acad. Sci. 1860:154–156.

Muttkowski, R. A. 1918. The fauna of Lake Mendota. Trans. Wis. Acad. Sci. Art. Let. 19:174–482.

Pilsbry, H. A. and Johnson, C. W. 1898. A classified catalouge, with localities, of the land Mollusca of North America, north of Mexico. (reprinted from the Nautilus, August 1897—April 1898.).

Wiswall, (Mrs.) E. C. 1897. Shells of southern Wisconsin. Nat. Sci. Journ. 1 (2):47–48.

The system of classification followed in this paper is that used by Baker in his recent monograph, with additions. That used for the land species is modified from the catalogue of Pilsbry and Johnson cited above. It is not to be presumed that the writer's arrangement of the groups of land forms is anything more than a convenience.

In all, one hundred and fifty species and varieties are recorded from Dane County. The following short list will give an idea of the distribution of these species into the major groups.

Fresh water univalves	53
Land univalves	25
Unionidae (bivalves)	42
Sphaeriidae (bivalves)	30
Total	150 (species and varieties)

Of interest is the fact that four species are herein added to those already known from the State. They are: *Pisidium concinnulum* Sterki; *P. minutum* Sterki; *P. pusillum* Jen.; *Radix auricularia* (Linn.). The occurrence of *Gyraulus crista* (Linn.)., in abundance, *living,* in the swamps near Lakes Mendota and Wingra is worthy of mention. Also notable is the recent discovery of *Acella haldemani* (Desh; Binney) as a fossil in the marl at the margin of University Bay, Lake Mendota. The only other record of this species' occurrence in the State is that of Lapham, who recorded it from the Milwaukee River in 1852.

Undoubtedly further collecting in the area will add other forms to those included in the present list. This is especially true since so little of the county has been intensively examined for Mollusca.

It is to be hoped that this list will in interest many; those interested in molluscs from a popular viewpoint, as well as those interested from more technical viewpoints.

Any additions and corrections will be gratefully received.

The systematic list by species follows. Each name of a species or variety is brought out to the left-hand margin for ready reference; the localities where the species is known to occur are stated; the names in parentheses following the localities indicate the authority for the records at the places cited.

SYSTEMATIC CATALOGUE OF SPECIES

Class GASTROPODA

Subclass STREPTONEURA Spengel.
Order CTENOBRANCHIATA Schweigger.
Suborder PLATYPODA Lamarck.
Superfamily Taeniglossa Bouvier.
Family VALVATIDAE Gray.
Genus *Valvata* Muller.

Valvata tricarinata (Say).
Four Lakes (Lapham); Lake Mendota (Muttkowski, Baker); margin, University Bay, Lake Mendota; dredging, seven meters, Lake Mendota; Merrill Spring stream; Pheasant Branch, near mouth (Morrison).

Valvata sincera Say.
Four Lakes (Lapham); Madison (Lapham, Binney, Chadwick, Baker).
Family VIVIPARIDAE (Gray) Gill.
Subfamily LIOPLACINAE (Gill) Baker.
Genus *Campeloma* Rafinesque.

Campeloma integrum (Say).

Wisconsin River, "ascends as far as the dam at Kilbourn" (Baker).

Campeloma rufum (Haldeman).

Yahara River, Madison (Pearse, Morrison); sandy shallows, Lake Mendota; Black Earth Creek, Mazomanie; Koshkonong River, Rockdale; outlet of Lake Ripley, Cambridge (Morrison).

Family AMNICOLIDAE (Tryon) Gill.

Subfamily AMNICOLINAE Gill.

Genus *Amnicola* Gould & Haldeman.

Amnicola limosa porata (Say).

Madison, (Lapham, Binney, Chadwick); Lake Mendota (Muttkowski); University Bay, Lake Mendota; dredging off Picnic Point, Lake Mendota (Morrison).

Amnicola limosa parva Lea.

Lake Mendota (Walker, Baker); Lake Mendota, dredging, seven meters (Morrison).

Amnicola lustrica decepta Baker.

Lake Mendota (Hinkley, Baker); Lake Wingra (Bullock, Baker).

Amnicola walkeri Pilsbry.

Lake Wingra (Bullock, Baker).

Genus *Cincinnatia* Pilsbry.

Cincinnatia cincinnatiensis (Anthony).

Yahara River, Madison; stream, four miles east of Belleville (Morrison).

Subfamily LITHOGLYPHINAE Fisher.

Genus *Somatogyrus* Gill.

Somatogyrus depressus (Tryon).

Prairie Du Sac (Hinkley, Walker, Baker): Probably occurs on the Dane Co. side of the river.

Somatogyrus tryoni Pilsbry & F. C. Baker.

Black Earth Creek, Mazomanie; Koshkonong River, Rockdale; outlet of Lake Ripley, Cambridge (Morrison).

Family POMATIOPSIDAE Stimpson.

Genus *Pomatiopsis* Tryon.

Pomatiopsis lapidaria (Say).

Four Lakes, Madison (Lapham, Binney, Chadwick, Baker).

Family PLEUROCERIDAE Fisher.

Genus *Pleurocera* Rafinesque.

Pleurocera acuta tracta (Anthony).

Lake Mendota (Muttkowski); Yahara River, Madison (Juday, Morrison); sandy shallows, Lake Mendota; Koshkonong River, Rockdale; outlet of Lake Ripley, Cambridge; Black Earth Creek, Mazomanie (Morrison).

Collections upstream at Kilbourn (Baker), and downstream at Arena (Morrison), indicate its presence in the Wisconsin River within the limits of Dane County.

Subclass EUTHYNEURA Spengel.

Order PULMONATA Cuvier.

Suborder BASOMMATOPHORA A. Schmidt.

Superfamily LIMNOPHILA.

Family LYMNAEIDAE (Broderip) Baker.

Genus *Lymnaea* Lamarck.

Lymnaea stagnalis jugularis Say.

Fourth Lake (Lapham); Lake Mendota (Muttkowski, Baker).

Genus *Stagnicola* (Leach) Jeffreys.

Stagnicola palustris elodes (Say).

The Four Lakes (Lapham); Lake Mendota, Madison (Bullock, Baker); ponds, streams, and swamp, south of Lake Wingra; swamp, University Creek, University Bay, Lake Mendota (Morrison).

Stagnicola umbrosa (Say).

Lake Mendota (Bullock, Juday, Baker); near Madison (Wiswall, Baker); Windsor (Bullock, Baker).

Stagnicola umbrosa jolietensis (F. C. Baker).

Shore of Lake Mendota, Madison (Bullock, Wagner, Baker).

Stagnicola reflexa (Say).

Farwell's Mills, Madison (Baird, Binney, Chadwick, Baker).

Stagnicola emarginata angulata (Sowerby).

Four Lakes (Lapham); Madison (Lapham, Binney, Marston, Wiswall, Chadwick, Bullock, Baker); below old Chem. Lab., Lake Mendota (Wagner).

Stagnicola caperata (Say).

Pond, stream, south of Lake Wingra (Morrison).

Genus *Acella* Haldeman.

Acella haldemani ("Deshayes" Binney).

Fossil in Marl: Margin of University Bay, Lake Mendota (Morrison). Further search may reveal this species living in Lake Mendota.

Genus *Radix* Montfort.

Radix auricularia (Linn.).

A small but thriving colony of this European species has been found in the aquarium of the Botany Dept. Greenhouse, at the University of Wisconsin. The snails were accidentally introduced; probably on Elodea plants, from either Cincinnati (Bryan), or Philadelphia (Denniston).

Genus *Fossaria* Westerlund.

Fossaria parva (Lea).

Swamp, streams, south of Lake Wingra; Merrill Creek; swamp, four miles east of Belleville (Morrison).

Fossaria modicella (Say).

Stream, pond, south of Lake Wingra; Pumping Station outlet, University Bay, Lake Mendota (Morrison).

Fossaria obrussa (Say).

University Bay, Lake Mendota (Pearse); stream, swamp, ponds, south of Lake Wingra; Pheasant Branch, near mouth (Morrison).

Fossaria obrussa decampi (Streng).

Fossil: Lake Wingra, near Madison (Bullock, Baker).

Fossaria exigua (Lea).

Streams, south of Lake Wingra (Morrison).

Family PLANORBIDAE H. & A. Adams.

Genus *Helisoma* Swainson.

Helisoma antrosa (Conrad).

Four Lakes (Lapham); University Bay, Tenney Park shores, Lake Mendota, Madison (Morrison).

Helisoma antrosa unicarinata (Haldeman).

Lake Mendota (Muttkowski, Baker).

Helisoma trivolvis (Say).

Farwell's Mills, Madison (Baird, Binnay); Madison (Baird, Binney, Chadwick, Baker); Lake Monona, Lake Mendota, Madison (Bullock); swamp, University Creek; Pheasant Branch, near mouth; ponds, south of Lake Wingra; Koshkonong River, Rockdale (Morrison).

Helisoma pseudotrivolvis (F. C. Baker).

Near Lake Monona (Bullock); near Murphy Creek, near Lake Mendota, near Madison (Bullock, Baker).

Helisoma campanulata (Say).

Fourth Lake (Lapham); Lake Mendota (Muttkowski, Baker).

Genus *Planorbula* Haldeman.

Planorbula armigera (Say).

Ponds, stream, springs, swamp, south of Lake Wingra; swamp, University Creek, University Bay, Lake Mendota (Morrison).

Genus *Menetus* H. & A. Adams.

Menetus exacuous (Say).

Swamp, south of Lake Wingra; swamp, University Creek, University Bay, Lake Mendota (Morrison).

Menetus exacuous megas (Dall).

The record of this variety from Lake Monona (Dane Co.) by Hinkley is erroneous. The record should be Lake Monona, *Minnesota,* not Wisconsin, as shown by other specimens in the Hinkley collection (Baker).

Genus *Gyraulus* Charpentier.

Gyraulus hirsutus (Gould).

Canal, south of Lake Wingra; swamp, University Bay, Lake Mendota (Morrison).

Gyraulus deflectus (Say).

Fourth Lake (Lapham); stream, south of Lake Wingra; Merrill Spring; Pheasant Branch, near mouth; swamp, University Bay, Lake Mendota (Morrison). The record from Lake Monona was probably a lapsus pennae of Hinkley for Lake Monona, *Minnesota* (Baker).

Gyraulus deflectus obliquus (DeKay).

Near Madison (Bullock, Baker).

Gyraulus parvus (Say).

Lake Mendota (Muttkowski, Bullock, Baker); dredging, seven meters, Lake Mendota; Yahara River, Madison; Merrill Creek; Merrill Spring stream; ponds, stream, swamp, south of Lake Wingra; swamp, University Creek, University Bay, Lake Mendota (Morrison).

Gyraulus altissimus (F. C. Baker).

Fossil in marl: near Lake Wingra (Bullock, Baker).

Gyraulus umbilicatellus (Cockerell).

Windsor (Bullock, Baker).

Gryaulus crista (Linn.).

Ponds, swamp, (on water plants) south of Lake Wingra; swamp, University Creek, University Bay, Lake Mendota (Morrison).

Family ANCYLIDAE Menke.

Subfamily FERRISSINAE Walker.

Genus *Ferrissia* Walker.

Ferrissia kirklandi (Walker).
University Bay, Lake Mendota (Juday, Baker).
Family PHYSIDAE Dall.
Genus *Physella* (Haldeman) Baker.

Physella ancillaria (Say).
University shores, University Bay, Lake Mendota (Wagner).

Physella sayii (Tappan).
Along shore, Lake Mendota, Madison (Wagner); swamp, University Bay, Lake Mendota; Yahara River, Madison; ponds, south of Lake Wingra (Morrison).

Physella sayii crassa (Walker).
Lakes Monona and Mendota (Baird, Bullock, Muttkowski, Wagner, Baker).

Physella warreniana (Lea).
Pheasant Branch, near mouth; swamp, University Creek, University Bay, Lake Mendota; Yahara River, Madison; canal, streams, south of Lake Wingra (Morrison).

Physella gyrina (Say).
Farwell's Mills, Madison (Baird, Binney, Chadwick, Baker); stream, south of Lake Wingra (Bullock, Baker); ponds, stream, canal, south of Lake Wingra; swamp, mouth of University Creek, University Bay, Lake Mendota; Merrill Creek (Morrison).

Physella gyrina hildrethiana (Lea).
Sun Prairie (Bullock).

Physella integra (Haldeman).
University shore, Lake Mendota, Madison (Wagner); rocky shore, east of University Bay; shores in Tenney Park, Lake Mendota; Yahara River, Madison; Koshkonong River, Rockdale; outlet of Lake Ripley, Cambridge (Morrison).

Physella walkeri (Crandall).
Merrill Springs, Lake Mendota (Pearse, Baker); Lake Mendota (Bullock, Muttkowski, Baker).

Physella michiganensis (Clench).
Merrill Spring (Morrison).
Genus *Aplexa* Fleming.

Aplexa hypnorum (Linn.).

Windsor (Bullock, Baker); swamp, north of Picnic Point. Lake Mendota, Madison; ponds, swamp, south of Lake Wingra; swamp, near outlet, Lake Ripley, Cambridge (Morrison).

Superfamily AKTEOPHILA

Family AURICULIDAE

Genus *Carychium* Muller.

Carychium exiguum (Say).

Swampy ground, south of Lake Wingra; along Merrill Spring stream; swamp, four miles east of Belleville (Morrison).

Suborder STYLOMMATOPHORA

MONOTREMATA

Vasopulmonata

ORTHURETHRA

Family VALLONIIDAE

Genus *Vallonia* Risso.

Vallonia costata (Muller).

Sunset Point, three miles west of Madison; swamp, along University Bay; along Merrill Spring stream; in willows, south of Lake Wingra (Morrison).

Vallonia pulchella (Muller).

Sunset Point, three miles west of Madison; along Merrill Spring stream; along Merrill Creek; swampy ground, south of Lake Wingra; Picnic Point, near University Bay; swamp, four miles east of Belleville (Morrison).

Family PUPILLIDAE

Genus *Strobilops* Pilsbry.

Strobilops affinis Pilsbry.

Swampy ground, south and west of Lake Wingra; Sunset Point, three miles west of Madison; along Merrill Creek; along the outlet of Lake Ripley, Cambridge (Morrison).

Genus *Pupoides* Pfeiffer.

Pupoides marginata (Say).

Sunset Point, three miles west of Madison (Morrison).

Genus *Gastrocopta*

Gastrocopta armifera (Say).

Sunset Point, three miles west of Madison; bluffs, northwest margin of Lake Mendota (Morrison).

Gastrocopta contracta (Say).

Bluffs, northwest margin of Lake Mendota; along Merrill Creek; in willows, south of Lake Wingra; Sunset Point, three miles west of Madison (Morrison).

Gastrocopta tappaniana (C. B. Adams).

Swampy ground, south of Lake Wingra; along Merrill Creek; swamp, four miles east of Belleville (Morrison).

Gastrocopta pentodon (Say).

Bluffs, northwest margin of Lake Mendota; Sunset Point, three miles west of Madison (Morrison).

Genus *Vertigo* Draparnaud.

Vertigo ovata (Say).

Swampy ground, south of Lake Wingra; swamp, four miles east of Belleville (Morrison).

Vertigo milium (Gould).

Swampy ground, south of Lake Wingra (Morrison).

Family COCHLICOPIDAE

Genus *Cochlicopa* (Ferussac) Risso.

Cochlicopa lubrica (Muller).

Madison (Lapham); near springs, south of Lake Wingra; bluffs, northwest margin of Lake Mendota (Morrison).

HETERURETHRA

Superfamily ELASMOGNATHA

Family SUCCINEIDAE

Genus *Succinea* Draparnaud.

Succinea retusa Lea.

Swampy ground, south of Lake Wingra (Morrison).

Succinea avara Say.

Swampy ground, south of Lake Wingra; bluffs, northwest margin of Lake Mendota; swamp, four miles east of Belleville (Morrison).

SIGMURETHRA

Superfamily HOLOPODA

Family HELICIDAE

Subfamily POLYGYRINAE

Genus *Polygyra* (Say) Pilsbry.

Polygyra monodon (Rackett).

Along stream, south of Lake Wingra (Morrison).

Polygyra monodon fraterna (Say).

Swampy ground, south of Lake Wingra; bluffs, northwest margin of Lake Mendota (Morrison).

Polygyra multilineata (Say).

Madison (Lapham); swampy ground, south and west of Lake Wingra (Morrison).

Superfamily AULACOPODA

Family ZONITIDAE

Subfamily ZONITINAE

Genus *Vitrea* Fitzinger.

Vitrea hammonis (Strom.).

Woods, south of Lake Wingra; Picnic Point, near University Bay; along Merrill Creek (Morrison).

Vitrea indentata (Say).

Bluffs, northwest margin of Lake Mendota (Morrison).

Genus *Euconulus* Reinhardt.

Euconulus fulvus (Draparnaud).

Swampy ground, south of Lake Wingra; Sunset Point, three miles west of Madison (Morrison).

Subfamily ARIOPHANTINAE

Genus *Zonitoides* Lehmann.

Zonitoides arboreus (Say).

Madison (Lapham); bluffs, northwest margin of Lake Mendota; swampy ground, south of Lake Wingra; Picnic Point, near University Bay; Sunset Point, three miles west of Madison; swamp, four miles east of Belleville (Morrison).

Family LIMACIDAE

Genus *Agriolimax* Morch.

Agriolimax campestris (Binney).

Bluffs, northwest margin of Lake Mendota; Picnic Point, near University Bay, Madison; swampy ground, south of Lake Wingra (Morrison).

Family ENDODONTIDAE

Subfamily ENDODONTINAE

Genus *Pyramidula* Fitzinger.

Pyramidula alternata (Say).

Sunset Point, three miles west of Madison (Morrison).

Genus *Gonyodiscus* Fitzinger.

Gonyodiscus cronkhitei anthonyi Pilsbry.

Madison (Lapham); swampy ground, south of Lake Wingra; along Merrill Creek; along outlet of Lake Ripley, Cambridge (Morrison).

Genus *Helicodiscus* Morse.

Helicodiscus parallelus (Say).

Bluffs, northwest margin of Lake Mendota; in willows, south of Lake Wingra; Sunset Point, three miles west of Madison (Morrison).

Class PELECYPODA Goldfuss.

Order PRIONODESMACEA Dall.
Superfamily NAIADACEA Menke.
Family UNIONIDAE (d'Orbigny) Ortmann.
Subfamily UNIONINAE (Swainson) Ortmann.
Genus *Fusconaia* Simpson.

Fusconaia flava (Rafinesque).
Black Earth Creek, Mazomanie; Koshkonong River, Cambridge, Rockdale (Morrison).

Fusconaia flava parvula (Grier)
Outlet of Lake Ripley, Cambridge (Morrison).

Fusconaia undata (Barnes).
Wisconsin River (Schoolcraft, Barnes, Marston, Baker), at Prairie du Sac (Lapham), opposite Prairie du Sac (Morrison).

Fusconaia ebena (Lea).
Wisconsin River, "found as far as Kilbourn" (Baker).
Genus *Amblema* Rafinesque.

Amblema rariplicata (Lamarck).
Wisconsin River (Barnes, Baker), at Prairie du Sac (Lapham, Wiswall). Probably occurs within the boundaries of the county.

Amblema costata Rafinesque.
Koshkonong River, Cambridge, Rockdale (Morrison).
Genus *Quadrula* Rafinesque.

Quadrula fragosa (Conrad).
Wisconsin River (Marston, Wiswall, Chadwick, Hinkley), at Kilbourn (Baker). Possibly in the Wisconsin River in this area.

Quadrula pustulosa (Lea).
Wisconsin River (Marston, Baker) at Prairie du Sac (Lapham), opposite Prairie du Sac (Morrison).

Quadrula metanevra Rafinesque.
Wisconsin River (Schoolcraft, Barnes, Marston, Baker), at Prairie du Sac (Lapham), opposite Prairie du Sac (Morrison).
Genus *Tritigonia* Agassiz.

Tritigonia verrucosa (Rafinesque).
Wisconsin River (Douglass, Barnes, Bullock, Baker), at Prairie du Sac (Lapham), opposite Prairie du Sac (Morrison).
Genus *Plethobasus* Simpson.

Plethobasus cyphyus (Rafinesque).

Wisconsin River (Baker); Prairie du Sac (Dudley); Wisconsin River, opposite Prairie du Sac (Morrison).

Genus *Pleurobema* (Rafinesque) Agassiz.

Pleurobema coccineum (Conrad).

Black Earth Creek, Mazomanie (Morrison).

Pleurobema coccineum solida (Lea).

Wisconsin River (Marston, Baker), at Prairie du Sac (Lapham), opposite Prairie du Sac (Morrison.)

Genus *Elliptio* Rafinesque.

Elliptio dilatatus (Rafinesque).

"Inhabits the Wisconsin" (Douglass, Schoolcraft, Barnes); Wisconsin River (Lapham, Baker), opposite Prairie du Sac (Morrison).

Elliptio dilatatus delicatus (Simpson).

Outlet of Lake Ripley, Cambridge (Morrison).

Subfamily ANODONTINAE Ortmann.

Genus *Lasmigona* Rafinesque.

Lasmigona compressa (Lea).

Black Earth Creek, Mazomanie; outlet of Lake Ripley, Cambridge (Morrison).

Lasmigona costata (Rafinesque).

Wisconsin River (Douglass, Barnes, Lapham, Marston, Baker), at Prairie du Sac (Wiswall); Black Earth Creek, Mazomanie; Koshkonong River, Cambridge, Rockdale (Morrison).

Lasmigona complanata (Barnes).

Wisconsin River (Douglass, Barnes, Lapham, Baker), opposite Prairie du Sac; Black Earth Creek, Mazomanie; Token Creek, Koshkonong River, Rockdale (Morrison).

Genus *Anodonta* Lamarck.

Anodonta grandis Say.

University shore, Lake Mendota (Wagner); Lake Wingra (Baker); south margin, Lake Wingra; canal, south of Lake Wingra; Yahara River, Madison; sloughs, south end of Lake Monona; Koshkonong River, Cambridge, Rockdale; Black Earth Creek, Mazomanie; Wisconsin River, opposite Prairie du Sac (Morrison).

Anodonta grandis footiana Lea.

Madison Lakes (Bradley); Lake Mendota (Dudley, Baker); shallow water, University shore, Lake Mendota (Wagner); north of Picnic Point, Lake Mendota; west margin of Lake Monona; outlet of Lake Ripley, Cambridge (Morrison).

Anodonta (grandis) gigantea Lea.

University Bay, Lake Mendota, Madison (Pearse); Yahara River, Madison (Pearse); Lake Wingra (Bullock, Twenhofel). These records are doubtfully referrable to *gigantea.*

Anodonta marginata Say.

Fourth Lake (Lapham); Lake Mendota (Dudley); Yahara River, above Lake Kegonsa (Dudley); Token Creek, Token Creek (Morrison).

Genus *Anodontoides* Simpson.

Anodontoides ferussacianus (Lea).

Koshkonong River, Cambridge, Rockdale; creek, four miles east of Belleville; Black Earth Creek, Mazomanie (Morrison).

Anodontoides ferussacianus subcylindraceus (Lea).

Token Creek, Token Creek; outlet of Lake Ripley, Cambridge (Morrison).

Genus *Alasmidonta* Say.

Alasmidonta calceola (Lea).

Black Earth Creek, Mazomanie; creek, four miles east of Belleville; Token Creek, Token Creek (Morrison).

Alasmidonta marginata (Say).

Black Earth Creek, Mazomanie (Morrison).

Genus *Strophitus* Rafinesque.

Strophitus rugosus (Swainson).

Wisconsin River (Marston, Baker); Wisconsin River, opposite Prairie du Sac; Black Earth Creek, Mazomanie; Koshkonong River, Rockdale (Morrison).

Strophitus rugosus lacustris F. C. Baker.

Outlet of Lake Ripley, Cambridge (Morrison).

Subfamily LAMPSILINAE Ortmann.

Genus *Obliquaria* Rafinesque.

Obliquaria reflexa Rafinesque.

Wisconsin River (Marston, Wiswall, Baker); Wisconsin River, opposite Prairie du Sac (Morrison).

Genus *Obovaria* Rafinesque.

Obovaria olivaria (Rafinesque).

Wisconsin River (Marston, Baker), at Prairie du Sac (Lapham); opposite Prairie du Sac (Morrison).

Genus *Actinonaias* Fischer & Crosse.

Actinonaias carinata (Barnes).
Wisconsin River (Barnes, Lapham, Marston, Wiswall, Chadwick, Baker); Black Earth Creek, Mazomanie; Koskonong River, Rockdale (Morrison).
Genus *Truncilla* Rafinesque.

Truncilla truncata Rafinesque.
Wisconsin River (Marston, Baker), at Prairie du Sac (Lapham); opposite Prairie du Sac (Morrison).

Truncilla donaciformis (Lea).
Wisconsin River (Baker), at Prairie du Sac (Lapham); opposite Prairie du Sac (Morrison).
Genus *Leptodea* Rafinesque.

Leptodea fragilis Rafinesque.
"Inhabits the Wisconsin" (Schoolcraft, Barnes); Wisconsin River (Baker), at Prairie du Sac (Lapham), opposite Prairie du Sac (Morrison).
Genus *Proptera* Rafinesque.

Proptera alata megaptera (Rafinesque).
Wisconsin River (Douglass, Barnes, Lapham, Baker). Probably occurs, although no specific records are at hand.
Genus *Carunculina* Simpson.

Carunculina parva (Barnes).
Black Earth Creek, two miles west of Mazomanie (Morrison).
Genus *Ligumia* Swainson.

Ligumia recta latissima (Rafinesque).
Wisconsin River (Douglass, Barnes, Marston, Baker), at Prairie du Sac (Lapham), opposite Prairie du Sac (Morrison).

Ligumia ellipsiformis (Conrad).
Wisconsin River, opposite Prairie du Sac; Koshkonong River, Rockdale; outlet of Lake Ripley, Cambridge (Morrison).
Genus *Lampsilis* Rafinesque.

Lampsilis siliquoidea (Barnes).
"Inhabits the Wisconsin" (Douglass, Barnes); Wisconsin River (Lapham, Baker); Lake Mendota, Madison (Pearse); south margin, Lake Wingra; Koshkonong River, Cambridge, Rockdale; Wisconsin River, opposite Prairie du Sac (Morrison).

Lampsilis siliquoidea rosacea (DeKay).
Madison Lakes (Bradley); Lake Monona (Bullock, Baker); University shore, Lake Mendota (Wagner); Tenney Park shores, shores north of Picnic Point, Lake Mendota; west margin, Lake Monona (Morrison).

Lampsilis ventricosa occidens (Lea).

"Inhabits the Wisconsin" (Schoolcraft, Barnes); Wisconsin River (Lapham, Wiswall, Chadwick, Baker), at Prairie du Sac (Wiswall), opposite Prairie du Sac; Black Earth Creek, Mazomanie; Koshkonong River, Rockdale (Morrison).

Lampsilis ventricosa lurida Simpson.

Fourth Lake (Lapham); west margin, Lake Monona; outlet of Lake Ripley, Cambridge (Morrison).

Order TELEODESMACEA Dall.
Superfamily CYRENACEA Tryon.
Family SPHAERIIDAE Dall.
Subfamily SPHAERIINAE F. C. Baker.
Genus *Sphaerium* Scopoli.

Sphaerium sulcatum (Lamarck).

Stream, south of Lake Wingra; creek, four miles east of Belleville; Token Creek, Token Creek (Morrison).

Sphaerium crassum Sterki.

Yahara River, Madison (Juday, Morrison).

Sphaerium solidulum (Prime).

Yahara River, Madison; Black Earth Creek, Mazomanie (Morrison).

Sphaerium bakeri Sterki.

Koshkonong River, Rockdale; Token Creek, Token Creek (Morrison).

Sphaerium striatinum (Lamarck).

Outlet of Lake Ripley, Cambridge (Morrison).

Genus *Musculium* Link.

Musculium transversum (Say).

Black Earth Creek, Mazomanie; Koshkonong River, Rockdale (Morrison).

Musculium truncatum (Linsley).

Stream, south of Lake Wingra (Morrison).

Musculium rosaceum (Prime).

Pheasant Branch, near mouth (Morrison).

Musculium securis (Prime).

Swamp, south of Lake Wingra; along University Bay, Lake Mendota (Morrison).

Subfamily PISIDIINAE F. C. Baker.
Genus *Pisidium* C. Pfeiffer.

Pisidium idahoense Roper.

Lake Mendota (Juday, Baker); dredging, off Picnic Point, Lake Mendota (Morrison).

Pisidium compressum Prime.

Wisconsin River, opposite Prairie du Sac; Pheasant Branch, near mouth; Koshkonong River, Rockdale; outlet of Lake Ripley, Cambridge; creek, four miles east of Belleville (Morrison).

Pisidium fallax Sterki.

Koshkonong River, Rockdale (Morrison).

Pisidium punctatum Sterki.

Yahara River, Madison (Morrison).

Pisidium variable Prime.

Dredging, off Picnic Point, Lake Mendota (Morrison).

Pisidium glabellum Sterki.

Merrill Spring (four miles west of Madison) (Morrison).

Pisidium adamsi Prime.

Stream, south of Lake Wingra; Yahara River, Madison (Morrison).

Pisidium sargenti Sterki.

Outlet of Lake Ripley, Cambridge (Morrison).

Pisidium neglectum Sterki.

Stream, south of Lake Wingra (Morrison).

Pisidium noveboracense Prime.

Merrill Spring; Merrill Spring stream; springs, along Merrill Creek; spring fed streams, south of Lake Wingra; Yahara River, Madison (Morrison).

Pisidium scutellatum Sterki.

Sandy shallows, Tenney Park shore, Lake Mendota (Morrison).

Pisidium walkeri Sterki.

Pheasant Branch, near mouth (Morrison).

Pisidium roperi Sterki.

Swamp, south of Lake Wingra; swamp, north of Picnic Point, Lake Mendota (Morrison).

Pisidium politum Sterki.

Pheasant Branch, near mouth (Morrison).

Pisidium abditum Haldeman.

Stream, south of Lake Wingra (Morrison).

Pisidium levissimum Sterki.

Springs, forest ponds, south of Lake Wingra (Morrison).

Pisidium rotundatum Prime.

Forest ponds, swamp, south of Lake Wingra; swamp, north of Picnic Point; swamp, University Bay, Lake Mendota (Morrison).

Pisidium minutum Sterki.

Spring fed stream, south of Lake Wingra (Morrison).

Pisidium subtruncatum Malmgren.

Dredging, off Picnic Point, Lake Mendota (Morrison).

Pisidium concinnulum Sterki.

Stream, south of Lake Wingra; outlet of pumping station, University Bay, Lake Mendota (Morrison).

Pisidium pusillum Jenyus.

Forest ponds, swamp, south of Lake Wingra; swamp, University Bay, Lake Mendota; swamp, four miles east of Belleville (Morrison).

THE HYPODERMAL GLANDS OF THE BLACK SCALE, SAISSETIA OLEAE (BERNARD)

I. The Dorsal Glands

Wm. S. Marshall

Not long ago there appeared an article (3) in which the statement was made that very little is known of the hypodermal glands of the Coccidae and that some of the work which has been published on this subject is not always detailed or correct. Several months before the appearance of this paper, work was started upon the hypodermal glands of the black scale, *Saissetia oleae;* work not at first so much about the structure of the glands and the functions of their secretions as upon their origin. The work enlarged as it went on and a study of structure was added to that of development; the other question, function, has been omitted. It is generally the practice to call all hypodermal glands of the Coccidae, wax glands, a classification which may not be entirely true. To avoid any mistake it has been deemed advantageous to classify these hypodermal glands as to their position upon the insect's body and they have been divided into dorsal and ventral glands; only those of the first category are described in this paper. Besides the glands, if they are all such, there are the sense organs and setae upon this surface of the scale insect's body; these, at least at present, will not be described and this paper is restricted to the hypodermal glands upon the dorsal surface.

The methods used in preserving the scale insects were four of the standard solutions, Carnoy, Kahle, Tower and Bouin; the first two were found to be better than the others. A number of stains were tried; iron haematoxylin was used for a number of slides but most of the sections were stained in Delafield's haematoxylin followed by an aqueous solution of red eosin, Bordeaux red or acid fuschin; these colored the cuticula. An old method of staining with pyroligneous acid and haematoxylin was found to be very good as it both stained the tissues and darkened the cuticula. The ordinary formula was changed by decreasing the amount of haematoxylin. The slides remained in this solution a few hours and then a large part of the haematoxylin was removed by acid alcohol; the preparations were then placed in tap water for ten to twenty minutes to regain their blue color and mounted. In several editions of Bolles-Lee's Microtomist's Vade-mecum this method is referred to as follows: "Burchardt's pyroligneous acid haematoxylin would seem to be superfluous at least." The preparation consists in dissolving 2 gr. potassium alum in 130 gr. pyroligneous acid and add to this 0.5 gr. haematoxylin dissolved in 70% alcohol. As already mentioned a much smaller amount of haematoxylin was found to give better results. The solution of pyroligneous acid with potassium can be used for coloring the cuticula and then followed by some other stain for the tissues.

Sections of the embryo show that the hypodermis is about the same over the entire body, but before emergence a difference in the thickness of this layer is noticed between that part covering the dorsal and the same layer on the ventral surface of the body. Dorsally the hypodermis is about twice as thick as the cuticula; the nuclei of its cells are elliptical in outline with their longitudinal axis parallel to the body's surface (fig. 1); there are no cell boundaries discernible. Over the ventral surface the nuclei are more flattened, with only a strand of cytoplasm connecting them with each other. The cuticula on the dorsal part of the body is thicker than that covering the ventral surface.

The very young larvae, those which have been out of the egg but a few hours, are small and active; before they permanently settle they wander over the surface of the leaf and, even after they have become fixed, they may change their location as they are often found, of different sizes, walking over the plant. Sections of these very young larvae show the layers of hypodermis and cuticula to be about what they were in the old embryos; there are marked differences in both layers upon dorsal and ventral surfaces, but transitions between the extremes of the two can readily be found. Both layers are thicker on the dorsal (fig. 2) than on the ventral surface but in these youngest larvae no traces could be found of any developing hypodermal glands; this was due either to the small size of the cells and the thinness of the cuticula or they do not begin to develop until the first instar is several days old. The nuclei of the hypodermal cells were plainly visible but no cell boundaries could be seen; these cells are not numerous over the surface of the body in this early stage; in a longitudinal section of the abdomen only four to six nuclei were seen in each segment. These statements regarding the size of the hypodermal cells are very general, as many exceptions can be found in different places on both dorsal and ventral surfaces. In transverse sections one can see at the lateral margins a gradual change in the size of the hypodermal cells from the larger dorsal ones to the smaller and more flattened cells on the ventral surface, also a crrresponding decrease in the thickness of the cuticula. The largest cells in the hypodermal layer are those, dorsal on the head, above the supraoesophageal ganglion. At different areas on the dorsal surface some of the nuclei assume a spherical shape (fig. 3), but elongated nuclei are more abundant; ventrally all the nuclei are flattened. In the hypodermis a number of mitotic figures can be seen, both nuclei and cells becoming more numerous as the young scale insect increases in size.

The larvae during their first instar increase very much in size and show great changes in the thickness of the cuticula and of the hypodermis. Quayle and Rust (13) state that during the first instar the young larvae increase in size from 0.35 mm.X 0.2 mm. to 0.7 mm.X 0.35 mm. and that the first stadium lasts from a month to six weeks. This long stadial period accounts for the changes which take place in the hypodermis and the gland cells and why both are so different towards the end of the first stadium from what is found in the newly hatched larva. A few days makes a marked difference in the size of the hypodermal cells and in the thickness of the cuticula. Over the dorsal and the ventral surfaces of the body the proportionate differences noticed in the embryo are still observed; what this is can be seen by comparing figures three and four with figure one; these are all drawn to the same scale.

The earliest noticeable appearance of the glands (fig. 5) was found in small, first instar larvae after they had settled on the plant and increased slightly in size. No gland was found without its pore through the cuticula; in fact when hunting for the glands in the earliest stages it was easier to find the pore in the cuticula and locate the gland in this way than to attempt to first find the glands themselves. A great many more pores were found than perfect glands; it was difficult to find both pore and gland well shown in the same section and they were, at this early stage, too small to follow from one section to the next. As already mentioned the large cone shaped pore through the cuticula was not difficult to find and it, the first trace of the developing gland, was proportionally quite large; at the upper surface of the cuticula it was narrow, but increased in diameter towards the inner surface of the hypodermis. About the first formation of the pore we know nothing and can only suppose that the underlying cell failed to secrete cuticula except the thin outer layer which is present and through which is the small opening allowing the secretion of the gland to pass out.

At first but a single cell of the hypodermis appears to take part in the formation of the gland and this cell shows but little difference from the others of this layer except that its shape is changed by its protrusion into the pore. Having examined many of these early glands, similar to figure five, I am unable to say whether the gland first appears as a single cell or is composed of more than one; none of them showed any trace of a multicellular origin, although they very early have more than a single nucleus. Examining many of them and from different specimens one would think that two or more nuclei within the boundary of the cell could easily be distinguished; this was not observed.

When the glands begin to increase in size, some of them lie more or less parallel to the surface of the cuticula, others protrude into the body cavity away from the hypodermis. The former of these are generally located where some organ of the body lies adjacent to the hypodermis and the gland is thus unable to push as far away from the neighboring hypodermal cells as if there was no tissue at their base. Figure six shows such a developing gland which in its growth has crowded against the cells of the hypodermis. The gland now shows quite an increase in size, much more so than do the regular hypodermal cells, and its nucleus is much larger; this refers to the main nucleus, probably the original one, as the others are no larger than those of the regular hypodermal cells. The changes which have so far taken place in the gland are its multinuclear condition and its increase in size.

The next change in the gland is the appearance of a vacuole, small at first but increasing in size with the growth of the gland of which it soon becomes the largest part. The position of this vacuole (fig. 7) is constant; it is found in the large part of the pyriform gland and between the nucleus and the duct like portion. As the main part of the gland has increased in size and pushed out into the haemocoele there is always a narrow stem-like part which connects it with the exit of the cuticular pore. This tubular part of the gland often has the appearance of a regular duct and, whatever its structure, it functions as an exit for the secretion of the gland which has collected within the large vacuole or bladder.

The further growth of the gland means principally an increase in its size and especially of the vacuole; more nuclei appear and two or three may be seen in a section. During the growth of the glands there is some difference in their general appearance; this is caused by the pressure against them of parts within the body causing them to be more or less intrahypodermal or they may not be subject to such pressure and then protrude free into the cavity of the insect's body. Figures nine and ten show glands taken from the dorsal surface of the same larva. Figure nine is of a gland located about midway between the median axis of the body and its margin. In this situation there are no large organs in the haemocoele and the gland in its growth is free to push down and acquire its normal shape. Figure ten is taken from the median dorsal part of the same insect; it is in a position where the alimentary tract pushes up against the dorsal wall of the body and the gland has in part grown by pushing against the neighboring cells of the hypodermis.

During the growth of the gland the regular hypodermis has increased in thickness as has also the cuticular layer and the relative thickness of these layers varies in different parts of the dorsal surface of the insect's body. The pore through the cuticula is necessarily longer, but it has the same relative shape that it had in the younger larvae; it gradually widens from the outer towards the inner surface of the cuticula, but it is not so wide relative to its length as in the earlier stages.

These hypodermal glands reach their maximum growth (fig. 11) towards the end of the first instar and show no difference except in size from those just described. The appearance of the wall of the gland relative to the size of the vacuole depends somewhat upon how near the center the section is cut. No cell boundaries can be found but there are a number of nuclei and of these there is always one, probably the original of the earliest stage, considerably larger than any of the others. In this as in succeeding stages there is quite a difference in the thickness of the hypodermal and cuticular layers, depending upon what part of the dorsal wall is examined; there is also a difference in the shape of the cells of the former layer; these are generally longer in the median part of the body, but exceptions to this can be found.

The problem of the comparative age of the specimens which have been sectioned and studied in this work is one about which little can be said and the criterion used was the development of the glands in one specimen as compared with their condition in the others. This has been followed and no attempt made to rear a number of marked specimens which could be removed and sectioned at stated intervals. It was at one time thought that the width of the specimens might be used as a comparison, but then a greater or less convexity of the body might change this and it soon became evident that sometimes a narrower insect showed a further development of the glands and a thicker cuticula than one which was wider.

A subject closely connected with this was the appearance of the second type of gland, also of its origin. Judging from two specimens sectioned, these were in the process of ecdysis, it can be said that the first type of dorsal gland is for the first instar and the second type appears just before or during the change from first to second larval stage; this last type of gland, with changes which will later be described, lasts until the insect becomes mature and probably until its death. That these two specimens were in the process of ecdysis was shown by the outer layer of cuticula being removed from an underlying one; in this outer layer, the cuticula of the first instar, pores were found of the first type of gland, none of the second type, while in the underlying cuticula, that of the second instar, the pores all showed the stopper characteristic of these glands (fig. 12). One also noticed that in these two specimens all sections of the tracheae enclosed a smaller tube, the intima of the tracheae of the first instar; this had not been cast out because the cuticula of the first instar had not yet been discarded.

The regular glands (fig. 11) found in the first instar larvae and which no doubt secrete the wax covering the dorsal surface of the body during this period of the insect's life, apparently decrease in size towards the end of the first instar, but whether the second type of glands becomes modified from them or develops as a new set is uncertain; that many of them do develop as new glands must be true as there are very many more present in the second instar than while the insect is in its first larval stage. The pore through the cuticula leading to the surface is quite different in the two and the presence of the stopper in the gland of the second type and the increase in thickness of the cuticular layer and later, the enlargement of the outlet, the cavity in the cuticula, give the differences which readily distinguish the one type from the other.

An early appearance of the second type of glands, those developing after the first ecdysis, has been found in a number of specimens and is well shown in that one where the cuticula of the first instar is being cast. The stopper (fig. 13) of the pore is distinctly shown in the cuticula and protrudes a little below its inner surface. Its wall is thick and it is easily seen in all sections cut through the center of the pore; in the older specimens, when the rest of the pore, the cuticular cavity, widens, there are many sections of the gland in which the stopper is not seen; in these no outlet to the exterior is shown, the sections being cut to one side of the stopper. This peculiar, short, tube-like piece of the cuticula, the stopper, is very similar in the black scale to a corresponding port found in other scale issects (8, 17). The second type gland cell in this early stage is very similar to a corresponding stage in the development of the first type of gland but, being from a much older and much larger larva the gland cell itself and the neighboring hypodermal cells are very much larger. This is readily seen in a comparison of figure twelve with figure five which is the earliest stage in the development of the gland of the first type.

The earliest gland of the second type (fig. 12) is very similar to the other hypodermal cells; it is longer, its nucleus is larger, and, where it touches the cuticula, it is in connection with a stopper. As in the first type of gland these also appear of unicellular origin, but their connection with other cells at a very early stage makes this uncertain.

When a slightly older gland is examined (fig. 14), one in which the vacuole, not always circular in outline although this is the most common shape, has appeared, it then becomes evident that more than one cell composes the gland and, as we go on in its development, we will see that, until the scale insect becomes mature, we are describing a multicellular gland; there is an association of smaller cells with the large one containing the vacuole. The number of these small cells is doubtful but there are at least four to each gland and probably more. The similarity of the vacuole in this gland to that in the early first type gland (fig. 7) is also noticeable not only in appearance, but in position within the gland. In the second instar, as in the first, one finds that the largest and longest cells of the dorsal hypodermis are near the median axis of the insect's body. Due to pressure from other cells on its free end the gland cell may be slightly curved.

So far in their development the similarity, except in size, between the first and second types of glands has been very marked; from now on they begin to differ and the second gland will not hereafter show any stage that can be compared with the corresponding development of the first type of gland. Continuing with the development of the gland of the second instar we find that it increases slightly in size, but that the greatest change is in the vacuole; this we will now call the bladder. This for some time retains its spherical, or it may be flattened, shape to finally become ovoid, with its narrow end pointed towards the apex of the gland or, put in another way, towards the outer surface of the cuticula. From the apex of the bladder the cell extends through the cavity in the cuticula until it reaches the stopper; this narrow part appears to form a tube through which the contents of the bladder may pass to the outer surface of the insect's body (fig. 14). With the increasing age of the scale insect the bladder appears to slowly pass into the cavity of the cuticula, but in reality the cuticula is increasing in thickness to gradually envelop the bladder and finally to surround it.

As the insect grows older the cells of the hypodermis continue to secrete more and more cuticula, adding this of course to the inner surface which becomes irregular. Where each gland is situated there is, as already mentioned, a conical cavity in the cuticular layer and this cavity situated as a cap over the gland becomes longer and longer as the cuticular layer increases in thickness (fig. 15). At first the newly secreted cuticula surrounding each cavity is only in part over the gland and its bladder is as yet entirely surrounded by the layer of hypodermal cells. With this growth it soon becomes apparent that each cuticular cavity contains a number of strands forming a reticulum; this is light colored at first, but becomes darker with the age of the insect. After the appearance of this reticulum one easily notices that each cuticular cavity is becoming larger, not only by the inward growth of the cuticula, but by lateral expansions on all sides; an early stage of this is seen in figure fifteen. This figure of only two of these cavities shows no connection between them but this has, to a slight extent, already taken place (fig. 16). This last figure is taken from the same specimen as the preceding, but at a position where no glands can be seen; it shows, however, that such a communication between the cuticular cavities has already begun.

Such a honeycombing of the cuticula is difficult to understand; of what use it can be to a permanently fixed insect is doubtful, but the figures from now on will all show that it does occur and is found in all specimens. This dissolution of a part of the cuticula must be due to some secretion and this probably comes from the small accessory cells of the gland, those which are the dark staining ones. These cells, at least some of them, become very dark in the stained specimens and the cells or their secretion continue into the cavity as a dark strand which passes along the margin of the bladder to become lost in the reticulum (fig. 20). There is also the possibility that these irregular cavities might be formed by an unequal secretion from the cells of the hypodermis. From the same specimen from which figure eighteen was drawn, two transverse sections are shown (fig. 19). The smaller of these figures is a surface view looking at the end of the stopper; the clear space surrounding this represents the apex of the cuticular cavity which appears lighter than the surrounding cuticula. Figure b shows a transverse section of the bladder and the cavity in the cuticula in which it lies. Here one can notice the reticulum which, closely surrounding the bladder, extends in all directions to the margin of the cavity.

In the specimens of this and somewhat later stages there is a difference in how far the bladder of the glands has become surrounded by the cuticula; neither it nor the cuticular layer have changed in appearance (fig. 17), but the latter is thicker and its cavities have increased in size. In all sections cut directly through the median part of the gland, the original gland cell is prominent and it and its large clear nucleus are easily seen, especially if the cell protrudes beyond the neighboring hypodermal cells. A view of a section cut in some other plane may show some of the other cells of the gland (fig. 18).

The shape of the cuticular cavities depends to a certain extent upon the thickness of the cuticular layer; in the long narrow ones, found especially at the posterior part of the body, the bladder is also long and thin and its outer end is, as in the shorter ones, more pointed than the end directed towards the center of the body. At this age the nucleus of the main gland cell has started to lose its regular appearance and its chromatin contents is crowded to one side. This is followed by a change in the cell near its nucleus (fig. 22); its regular structure has become modified and in its place there appears a loose reticular arrangement of the contents quite similar to what first appears in the cuticular cavities; this condition, with slight changes, remains until the cell disappears. The dark staining cells are readily found in every gland; each one has a long narrow extension passing into the cuticular cavity and extending to the side of the bladder (fig. 20). More than one of these cells is usually found in each gland. In these last two figures, twenty and twenty-two, the regular hypodermal cells are still normal and have not begun to disintegrate as occurs when the insect reaches maturity.

The duct passing from the bladder to the stopper is always present and easily seen in sections cut through the center of the gland and cuticular cavity. It develops from the thinner part of the original gland cell and such a development can be seen in figures twelve, fourteen and fifteen. After it is formed it remains unchanged for a considerable time during the growth of the gland, but, as the scale insect reaches maturity, the wall of the duct becomes darker and more distinctly seen; it becomes yellow or brown in color. At this time and until the maturity of the insect, the wall of the duct is thicker and darker near the apex of the bladder (fig. 21).

The addition to the inner surface of the cuticular layer which has been described, ceases after a time and in the full grown scale insects this layer is, relative to the size of the body, thinner than in the specimens that are half or three-quarters grown. As the insect becomes mature the increase in body size is due to egg formation and the retention in the body of the eggs until the embryo in each is well along in its development. The cuticula shown in the figures might be compared one stage with another if the magnification was the same, were it not that variations in the thickness of this layer occur on different parts of the dorsal wall of the body.

The most noticeable change to now take place is in the cells of the glands and of the hypodermis; this change is so great that in the oldest insects examined the hypodermis has disappeared and its cells and their nuclei together with those of the glands have all broken down and migrated, in part or entirely, into the cuticular cavities. This seems to be the most plausible explanation as these cavities now contain a dark and irregular mass in which are a number of small nuclear-like bodies; these are no doubt from the regular cells that have disappeared from their former and original position to finally pass into the cavities.

By a mature black scale we mean one within the body of which a number of well developed embryos are found; all the figures not yet mentioned, 23 to 27 inclusive, are from these mature insects. In following these figures one can notice what takes place until, in the last section shown (fig. 26) practically no hypodermis remains. This goes even further than is shown in this figure as in some specimens, evidently the oldest, no trace is left of any cytoplasm lying along the inner wall of the cuticular layer. The bladder appears to persist and the stopper is always present.

In the breaking up of the hypodermis and the glands the cells of the gland, especially what appeared to be the main one, lose the nucleus which becomes a dark staining, irregular mass represented by what appears to be the chromatin alone; later the contents of the cell changes to irregular strands. This cell now becomes clearer than it was; it is situated at the opening of the cuticular cavity into which it appears to pass (fig. 24). The beginning of this change was noticed in an earlier stage (fig. 22) and it seems probable that these figures represent the disintegration of the cell and its nucleus and their final disappearance into the cavity.

The number of these glands in the dorsal wall of the black scale is very large; they appear more numerous and crowded together in the third instar before it reaches maturity. In some sections or parts of a section the glands are crowded together as much as possible (fig. 15) and, as the scale insect increases in size, the glands spread a little further apart, probably due to a small amount of stretching of the cuticula; I know of no other way to explain it. Even after the insect has become mature, sections show that the cuticular cavities of the glands are not far apart (fig. 26). A view of the dorsal surface of the mature insect (fig. 27) gives one a better idea of their number and close proximity. This last mentioned figure would have been about the same as the one drawn if it had been taken from any other place on the dorsal wall; the glands themselves are not shown, but the figure shows the cuticular cavities and each one of these represents the position of a former gland.

In four specimens of very old insects that were sectioned, another condition was noticed which has so far not been described. In all of these insects the gland cells and those of the hypodermis had in part or entirely disappeared and in the cuticular cavity containing most of their contents was noticed a dark yellow, irregular mass; this appeared to partially fill some cavities and entirely fill others; this same yellow substance was noticed in what remained of the gland cells. This mass in one specimen was noticed as a fine layer over the inner surface of the cuticula. The meaning of this I do not know unless it is that the final stage is the formation within the cuticular cavities of a hard mass to completely block them; whether this comes to all insects of a certain age and shortly before their death is unknown.

The old scale insects are difficult to section as the hard cuticular covering makes it almost impossible to procure anything like a series. The best method tried was to cut the old insects into four or more pieces, after they were preserved, and then section each piece. When these were cut and mounted one could find, here and there, a section in which the cuticular layer was in its normal position in contact with the body; many sections had to be discarded because they were so badly broken that no piece could be found where cuticula and body were in normal relation to each other. Very often the cuticula was torn entirely away from the body.

SUMMARY

Two types of dorsal hypodermal glands occur in the black scale. The first type is present only in the first instar and these glands develop early in larval life from regular hypodermal cells; a vacuole soon appears in each gland and this soon grows to be its largest part. The gland communicates with the outside through a duct, part of the original gland cell, and a small opening in the cuticula. These are wax glands and secrete the thin layer of this substance covering the dorsal surface of the body.

The second type of gland first appears in the early sec-

ond instar and persists through the life of the insect, although it finally loses its normal shape and position. The gland develops from the hypodermis and its early stages are very similar to those of the first type gland. A vacuole appears in the original gland cell; this later becomes the bladder which connects with the outer surface through a duct and a small cuticular stopper. The cuticular layer increases in thickness by secretion from the regular hypodermal cells to finally surround the bladder, but leaving a cavity around it. This cavity increases in size by lateral enlargements; these are probably formed by some secretion dissolving a part of the cuticula. These lateral enlargements may increase until they communicate with each other. The use of these glands is not known and they, with the regular hypodermal cells, finally break down and pass into the cavity of the cuticula.

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Explanations of Plates

Abbreviations used in plates

Bl., bladder.
Ch., chorion.
Cut., cuticula.
Cut. Cav., cuticular cavity.
Gl., gland.
Hyp., hypodermis.
Vac., vacuole.

Plate 10

All the figures shown in this plate are of the first type of gland; they are all of the same magnification, X 1400 diameters.

Fig. 1. A transverse section through the dorsal wall of an embryo. Due to contraction during preparation the chorion, Ch., is not close to the cuticula, Cut., of the embryo.

Fig. 2. Section of a first instar larva shortly after its emergence from the egg. This is from the dorsal wall of the body, anterior and near the margin.

Fig. 3. From a transverse section of the body wall of the thorax of a young first instar larva a few days older than the preceding.

Fig. 4. From the same specimen as figure three, but from the ventral body wall of the thorax.

Fig. 5. Section from the dorsal wall of a young first instar larva. It shows the earliest noticeable appearance of the gland, Gl., which is as yet of about the same size as the neighboring hypodermal cells, but of a different shape.

Fig. 6. From a little older larva; the gland, Gl., is flattened against the cuticula by the pressure of some adjacent organ. The duct is cut a little to one side and it is not continuous to the outer surface of the cuticula.

Fig. 7. Gland from a first instar larva showing the early formation of the vacuole, Vac., within the gland, Gl.

FIG. 8. Transverse section of a gland showing the vacuole and two of the smaller nuclei.

FIG. 9. Gland from an older first instar larva.

FIG. 10. Two neighboring glands from the same larva as the preceding one; the section is from the median part of the dorsal body wall where the alimentary canal crowds up against it.

FIG. 11. Section of a gland from a nearly full grown first instar larva.

PLATE 11

FIG. 12. Section of a first instar larva in the process of ecdysis; its loosened cuticula, Cut., shows a pore of the first type gland. This figure is the earliest stage of the second type gland, Gl., at the end of which in the cuticular layer, Cut. ', is the stopper. X 1400.

FIG. 13. Diagram of a stopper in section, a, and surface view, b.

FIG. 14. Section from a young second instar larva showing the gland, Gl., containing the vacuole, Vac., and with three small secondary cells. X 1400.

FIG. 15. Two neighboring glands, Gl., each with bladder, Bl., from which a strand of cytoplasm or tube passes through the cuticular cavity to the stopper. The extra cuticular secretion is forming and has partially filled the cuticular cavities. X 940.

FIG. 16. Another section from the same specimen as preceding figure and showing the hypodermal layer, Hyp., with the enlarged cuticular cavities some of which are already connected with each other. X 940.

FIG. 17. Section of a gland from an older larva than the preceding two figures. The cuticular layer, Cut., has grown in thickness and now surrounds the bladder on all sides. Three of the smaller gland cells are shown touching or adjacent to the main one. X 940.

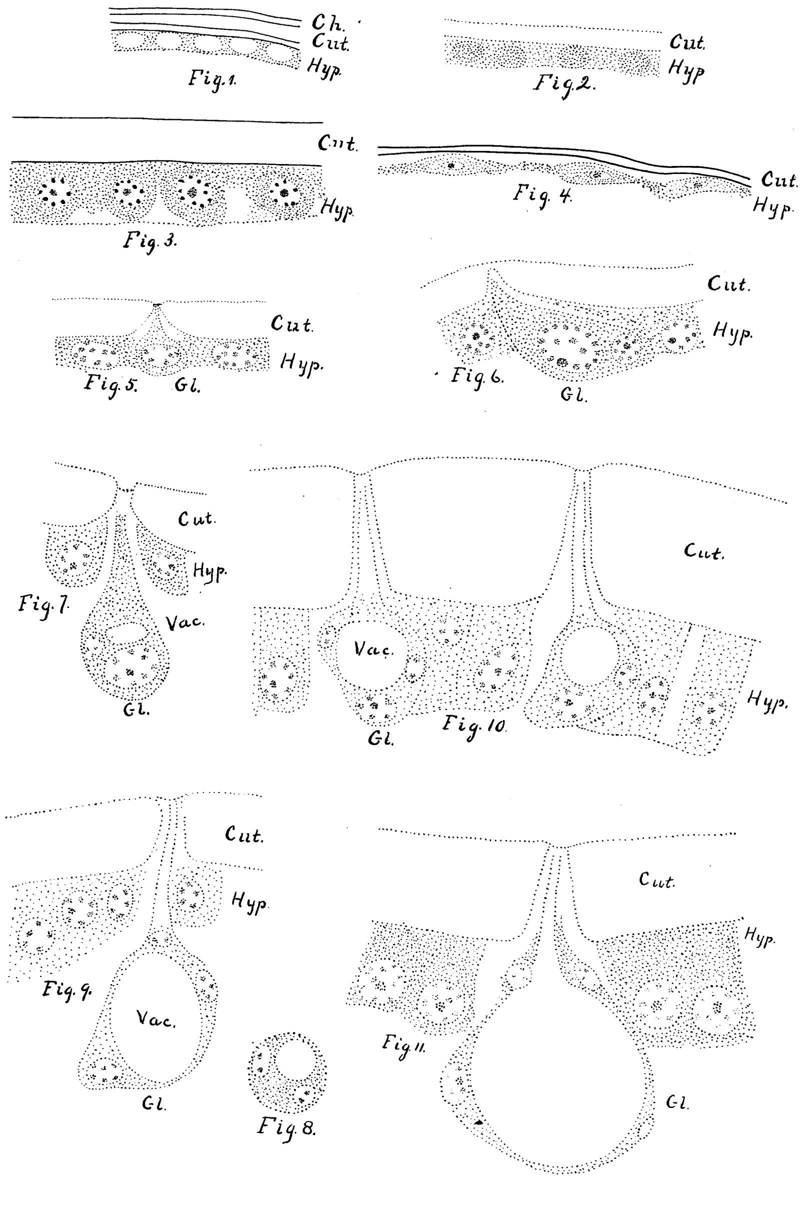
FIG. 18. Gland showing some of the accessory cells, not the main one shown in most figures. This is cut a little to one side; it shows the enlarged cuticular cavity but not the stopper. X 940.

FIG. 19. From same specimen as last figure, 18. This shows at *a* the surface view of a stopper with the apex of the cavity in the cuticular layer shown as a clear surrounding space; *b* a transverse section through the same cavity, but in the region of the bladder, Bl., around which is seen the reticulum within the cuticular cavity. X 940.

PLATE 12

FIG. 20. Gland with a much elongated cuticular cavity. The nucleus of the main gland cell, Gl., has lost its normal appearance. X 940.

FIG. 21. One of the ducts leading from the bladder to the stopper. This becomes hardened in the old insects and in many specimens is yellow and very noticeable. X 1400.


Ch.
Cut.
Hyp.
Fig. 1.
Cut.
Hyp
Fig. 2.
Cut.
Hyp.
Fig. 3.
Cut.
Hyp.
Fig. 4.
Cut.
Hyp.
Fig. 5.
Gl.
Cut.
Hyp.
Fig. 6.
Gl.
Cut.
Hyp.
Fig. 7.
Vac.
Gl.
Cut.
Vac.
Gl.
Fig. 10.
Hyp.
Cut.
Hyp.
Fig. 9.
Vac.
Gl.
Fig. 8.
Cut.
Hyp.
Fig. 11.
Gl.

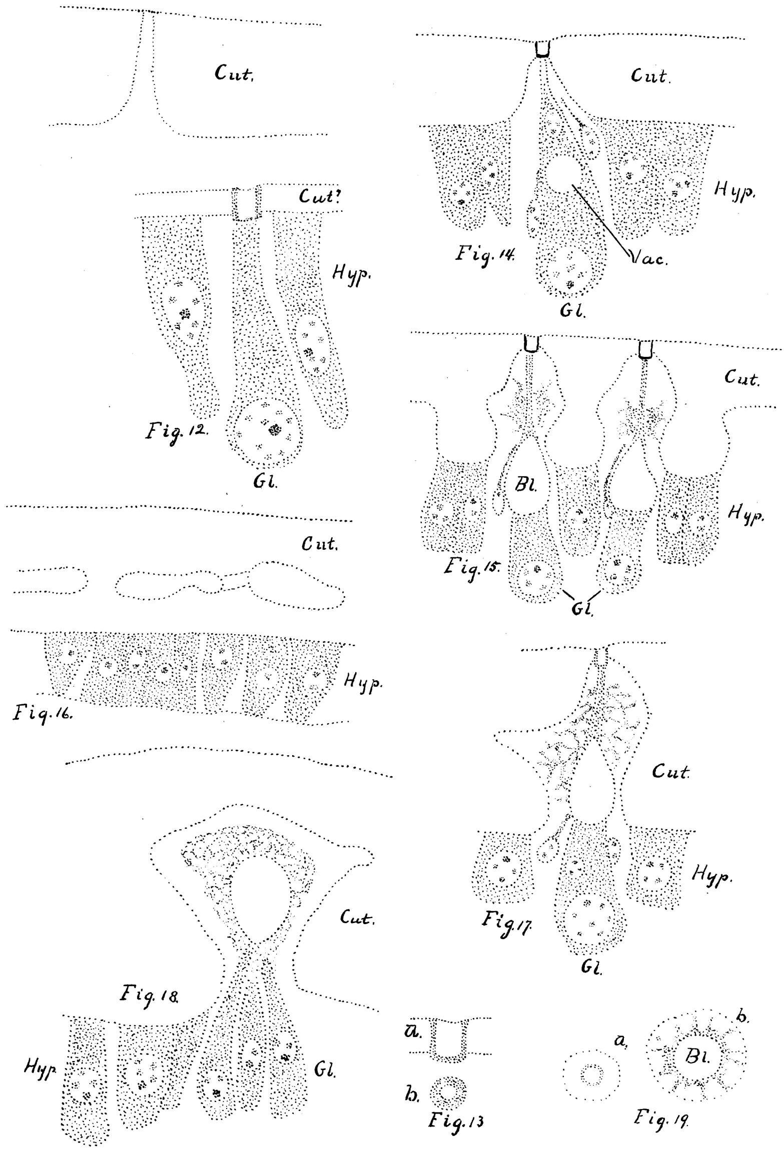

Cut.
Cut?
Hyp.
Fig. 12.
Gl.
Cut.
Hyp.
Fig. 14.
Vac.
Gl.
Cut.
Bl.
Hyp.
Fig. 15.
Gl.
Cut.
Hyp.
Fig. 16.
Cut.
Hyp.
Fig. 17.
Gl.
Cut.
Fig. 18.
Hyp.
Gl.
a.
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Fig. 13
a.
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Bl.
Fig. 19.

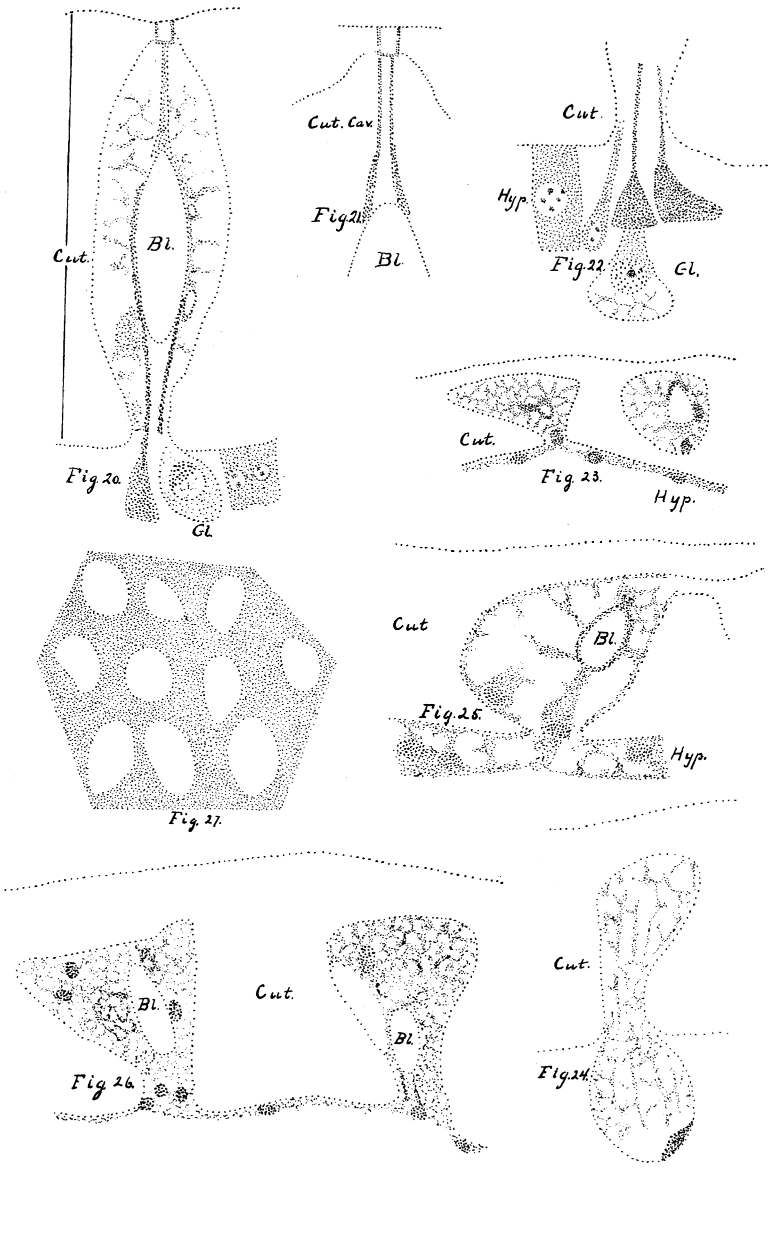
Cut.
Bl.
Fig. 20.
Gl.
Cut. Cav.
Fig. 21.
Bl.
Cut.
Hyp.
Fig. 22.
Gl.
Cut.
Fig. 23.
Hyp.
Cut
Bl.
Fig. 25.
Hyp.
Fig. 27.
Cut.
Bl.
Fig. 26.
Bl.
Cut.
Fig. 24.

FIG. 22. Showing one regular cell of the hypodermis, Hyp., and a few cells of the gland. The original large gland cell, Gl., has started to disintegrate; of the three other gland cells shown, two of them are the darker cells which no doubt secrete the fluid forming the reticulum. X 940.

FIG. 23. Showing the further disappearance of the hypodermis. Two cuticular cavities, neither cut through the center, do not show the stopper and the one to the right does not even show its communication with the hypodermal layer. The bladder is present and one is seen in the cuticular cavity to the right. This and the following figures are all taken from insects containing well developed embryos in their body. X 940.

FIG. 24. This specimen shows a quite large abnormal looking cell at the opening of the cuticular cavity and, at its base, what appears to be the remains of the nucleus. X 740.

FIG. 25. In this figure, as in all others of the old insects, the bladder is still present in the cuticular cavity and would be connected to the stopper by its duct were the section through the middle of the cavity. The hypodermis, Hyp., has lost its regular appearance and has begun to disappear. X 740.

FIG. 26. In this figure two of the cuticular cavities are shown, but neither cut near enough its center to show the stopper. The hypodermis has nearly disappeared, no doubt having migrated into the cuticular cavities. X 940.

FIG. 27. Surface view of an old black scale showing the spacing of the glands over the dorsal surface; the clear spaces are the cuticular cavities. X 220.

PRELIMINARY STUDIES OF THE INTRACELLULAR SYMBIONTS OF SAISSETIA OLEAE (BERNARD) *

A. A. GRANOVSKY

In a course of study of mosaic diseases of economic plants, many writers observed that sucking insects were able to transmit and disseminate infective principles, which cause the symptoms of these puzzling diseases. It has also been shown that insects are far more efficient in inoculation experiments of virous diseases than the modern methods of pathological technique. In looking for a possible explanation of these facts, a number of sucking insects have been examined for micro-organisms, hoping to learn something of the cause and nature of mosaic diseases.

In this search for internal micro-organisms, a series of insects, infesting numerous plants in greenhouses, were taken for preliminary study during the winter of 1924–25 and the following winters up to the present date. Different forms of organisms, varying from minute, highly refractive spherical bodies to rather large oval or considerably elongated yeast-like bodies, have been found inhabiting several species of aphids and scale insects. In their appearance and location within the insects they resembled the supposedly symbiotic organisms reported by several workers. These organisms were found to be especially numerous within the scale insects. Because of the unusualness of such association, attention has been given to one of the species of scale insects, namely, the black scale of California, *Saissetia oleae* (Bernard), feeding on oleander plants in the greenhouses. The reasons for selecting this species of insect for study of intracellular symbionts were as follows:

1. This scale insect was fairly abundant in number to insure sufficient material for study.

*Contribution from the Department of Economic Entomology, Wisconsin Agricultural Experiment Station, University of Wisconsin.

2. It was observed that the oleander leaves showed a considerable discoloration around the feeding punctures and in severe cases the leaves were slightly distorted on account of insect injury.

3. Every specimen of the insect showed the presence of a large population of yeast-like organisms, which are relatively large in size and consequently are convenient to study.

A Brief Historical Review

The symbiotic organisms of insects in general, and in Homoptera especially, were first reported by F. Leydig in 1854. He described free living lanceolate bodies in the lymph of *Lecanium (Coccus) hesperidum* Linn. and regarded them as parasitic. In 1858 Huxley discovered the symbionts in the embryos of parthenogenetic aphids. He called the tissue with these organisms the "pseudovitellus". This name was used by several workers later, applying it to certain cells in the developing ova. Metchnikov, 1866, in his embryological studies of aphids, coccids and psyllids, found the organisms infecting the ova, multiplying therein and distributing themselves within the developing embryos. He also used the term pseudovitellae for them.

J. D. Putnam in 1880 was the first in this country to observe the yeast-like bodies in the ovaries of *Pulvinaria innumerabilis* Rathvon. Besides giving an excellent description of the organisms, he considered them after Leydig to be parasitic. He also suggested that they may represent the spermatophores and may be instrumental in the fertilization of ova.

Until recently very little has been known concerning this subject. Only the works of Berlese, 1893, and Pierantoni, 1910, in Italy; those of Buchner, 1910–1928, and Lindner, 1895–1907, in Germany; Conte and Faucheron, 1907, in France; Sulc, 1910, in Czechoslovakia; Brain, 1923, in South Africa; and those of Shinji, 1919, Brues and Glaser, 1921, and Schrader, 1923, in this country, contributed to our knowledge of the intracellular symbionts of many insects, especially those belonging to Homoptera.

Several attempts have been made to classify the symbionts found in many insects. Moniez, 1887, was the first who made this attempt, naming the organism observed by Leydig in *Lecanium hesperidum* Linn. as *Lecaniascus polymorphus*. He based his description on the characters observed in culture, believing that he had isolated the organism. It was later shown, however, that he was dealing with a contaminated culture. Lindner in 1895 renamed the yeast-like bodies of this species of scale and placed it in the genus of Saccharomyces. Sulc in 1906–1910, and Buchner in 1912 erected several new genera with the description of a few new species of symbionts found in different insects. These are accepted by workers on the subject and have good possibilities of retaining their names in future literature on the subject. Brain in 1923, in his phenomenal work on classification "of the intracellular symbionts of insects with a short record of every known species" revised the whole subject and erected several new genera and described a number of new species of symbionts found in coccids. He also gives a brief account of previous work by other authors. His new genus Lecaniocola is of interest in this paper. This genus is, no doubt, closely related to Saccharomyces, but so far as is known no endospores have been observed in these yeast-like bodies which separate them from the latter genus. Another striking characteristic of the genus Lecaniocola is that the organisms placed in it are found in scale insects, especially those belonging to the sub-family Lecaniinae and are believed to be in symbiotic relationship with the insects. The organisms of this genus are found free in haemolymph or connective fat tissue, as contrasted with the symbionts, belonging to Kermincola Sulc, which are found in definite mycetom.

During the present study of symbionts in *Saissetia oleae* (Bernard) it was found that Conte and Faucheron in 1907, describing the organisms from *Lecanium hemisphericum* Targ., made a brief statement is regard to the presence of organisms in the black scale of California. This statement in a free translation is as follows:

"*Lecanium hemisphericum* is not the only coccid containing yeast forms. We have found them always present in very large numbers in *Lecanium oleae, Lecanium hesperidum, Pulvinaria floccifera,* etc. These present a different aspect from those in *Lecanium hemisphericum.* The comparative study of all forms only allows us to define their affinities".

This is the only original statement found in literature on the subject in regard to symbionts met with in *Saissetia oleae* (Bernard). It will be of interest to note, that Brain, in describing all species of symbionts known to him, does not list one from *Saissetia oleae,* although this insect occurs in South Africa on a number of plants such as olive, *Olea europaea* Linn., *Dovyalis caffra* Harv. and *Hibiscus* sp., but it is evidently not occurring on oleander, *Nerium oleander* Linn. in South Africa, for Brain omits this plant from his host list of the insect in question. A number of species of scale insects are reported by Brain as feeding on oleander, but there is no *S. oleae* among them. In Europe this scale feeds primarily on olive, while in this country it infests a number of plants such as orange, olive, oleander, live oak and many others.

Methods of Study with Results of Observations*

As was stated above, all individuals of *Saissetia oleae* (Bernard) are infested with the yeast-like organisms. If any of the young nymphs, mature females, or even the eggs are crushed on or between clean and sterile slides in a drop of normal salt solution, the organisms may be seen quite readily under low, or still better under the high power of a microscope. They are easily separated by the normal salt solution from the fat globules, and this enables one to study them without much trouble from any extraneous matter. Being heavier than the solution used, they always drop next to the slide, while the fat globules remain next to the cover glass. In such a simple preparation the symbionts are free in the normal salt medium and appear to be colorless, with several large vacuoles and conspicuously granular protoplasm, always having a few highly refractive bodies. Their general form is oval, elongated, yeast-like, often with the buds on the pointed polar end. (Plate 13, fig. 1.).

*In this connection I wish to express my sincere gratitude to Dr. W. S. Marshall and Dr. E. M. Gilbert for their constructive suggestions during the progress of this work.

The half-grown nymphs and young females invariably yielded a greater number of these organisms than the extremely young nymphs or older females. This is probably on account of the fact, that in the very young nymphs the symbionts did not have enough time for multiplication to reach their greatest number, while in the older, mature individuals, the symbionts are reduced in number due to disintegration or modification. Their development and increase in number, as well as subsequent disintegration is apparently running parallel with the accumulation and assimilation of adipose tissue within the insect.

The leaves of oleander, infested with the scales, were washed in sterile water and in normal salt solution and the washings examined for the organisms, but, in spite of repeated efforts, not a single yeast-like body, resembling the organism in question, was detected. This seems to indicate that the surface of the infested leaves is free from the organisms.

The scales were also washed in the normal salt solution in a watch-glass and their washings examined, but they, too, failed to yield the organisms. This, in its turn, indicates that the organisms are not present on the surface of the insects.

A sufficient amount of honey dew given off by this species of scale was collected and examined for the yeast-like bodies, but their presence was not detected, in spite of the fact that the honey dew was often rich in fungous and bacterial flora. Evidently they are not found in the honey dew of the insect, at least in their common forms; although very minute spherical and highly refractive bodies, not more than granules, were often observed to be present in the honey dew of these scale insects.

An attempt was made to study the multiplication of the organisms in hanging drop cultures, using the normal salt solution for the medium. To prevent contamination, every insect was passed quickly through an alcohol lamp flame several times before it was dissected on a sterile slide for study. Mercuric bichloride 1:500 was also used for sterilzation with equal success. Only a small amount of fat tissue of the insect containing the organisms was placed in hanging drop cultures. A suitable field under a microscope was then located and the approximate positions of all the organisms in view were sketched, paying particular attention to their forms, shapes, and budding. The position of the stage was also noted and microscopes were left undisturbed for the time of observation. It was repeatedly observed that the organisms may multiply for a short duration of time, although not rapidly. The buds as a rule develop at the pointed end, and only rarely small spherical buds may be produced at the rounded pole of the mother organism. The buds at first may have the appearance of only small spherical projections which gradually grow and increase in size, and, upon reaching about half of the size of the mother cell, they may separate. Often, however, the mature cell produces a long neck, at the end of which a small swelling begins to develop, and this swelling grows into a separate individual, as the result of drawing the neck between the two cells to a very fine point. Buds often persist until they are fully mature and only then separate. Most of the buds, however, leave the parent cells while they are quite small, and increase in size after their separation. It was found that the organisms in the normal salt solution multiply and increase in size quite rapidly only during the first 24 or 48 hours; later there is no sign of multiplication. In old cultures many organisms evidently disintegrated and disappeared. It was observed that greater growth was produced near the insect tissue present in the cultures, than in a pure normal salt solution. The organisms, evidently, in hanging drop cultures drew on their own reserves as well as on the insect tissue.

In the hanging drop cultures, and in the temporary normal salt solution preparations, many minute spherical bodies were also observed. They were often arranged in rosettes or were floating free in the medium. What they are, is not clearly known. They might be modified forms of the yeast-like organisms, or they may represent entirely distinct organisms living within the scale insect.

The internal structure of the yeast-like symbionts has been studied in smears, prepared in the ordinary method and stained with Orange G, acid Fuchsin, Safranin, Eosin, and Loeffler's methylene blue alone, or in their combinations. The best smears, showing the internal structure, were obtained with the combination of Orange G and aqueous Safranin. It may not be amiss to mention that it is extremely difficult to bring out the details of structure by various combinations of differential staining. Triple Flemming stain also gave good results when carefully destained.

The best smears show the presence of several large vacuoles, usually 3 or 4 in elongated and older symbionts, and only one or two in smaller and younger cells. The protoplasm is conspicuously granular and is arranged in streaks between the vacuoles. It often stains deeply in two or three places giving the impression of the presence of several nuclei, although it is doubtful if these deeply colored spots are nuclei. The presence of a number of minute clear spots is conspicuous. These are highly refractive and are scattered in the protoplasm, especially toward the pointed end of the organism, where budding takes place. (Plate 15, fig. 5–9).

In preparing the microscope sections, ordinary histological methods were followed with special precaution to dehydrate in the alcohols, as well as to clear in the xylol very gradually. The same can be said of infiltration in paraffin. A series of specimens were killed and fixed in Flemming's medium, Tower's No. 2, Kahle's and Bouins' fixing solutions. The best results were obtained with the Bouins' and Kahle's solutions, although Flemming's solution also gave fairly good results. The staining is very difficult, but after numerous trials as to combinations of differential stains, and the time required in each of them, it was found that the combination of Delafield Haematoxylin 20 minutes and the saturated aqueous solution of safranin for one and one-half minutes gave satisfying results. Two other combinations gave good results. One of them was Orange G, 10 minutes and cyanin 5 minutes, when fixed in Bouins' solution. The other was that of ordinary Flemming's triple stain.

After the cutting of serial sections of the nymphs and mature females, as well as the eggs, collected from under the shells of the insects, it was evident that the half-grown individuals had a higher population of the organisms than the mature females. The symbionts appeared to be intracellular in nature and were embedded in the connective fat tissue in great numbers, and were usually present free in the haemolymph. (Plate 13, fig. 2). The greatest number of them was found toward the perifery of the younger insects. In the mature females the symbionts were less numerous and were distributed more evenly throughout the whole insect, although most of them were restricted to the connective fat tissue. At this time there is a noticeable modification or disintegration of these micro-organisms, for it is difficult to explain the reduction of their number in any other way. They probably break down into minute and hardly noticeable granules or gradually disappear entirely as the amount of adipose tissue is considerably digested and reduced by metabolic processes with the age of the insect.

A number of serial sections reveal the entrance of these micro-organisms into ova soon after their differentiation from nurse cells and follicular epithelial cells, and before the early stage of clearage. The manner in which the symbionts enter the eggs is not clear; it is evident, however, that they gain entrance in more than one way. They are observed to enter the egg at the anterior end through the nurse cells evidently with the stream of the nutriative material, and are often lodged between the epithelial layer and nurse cells, as well as the ovarian chamber. (Plate 14 fig. 3). Other sections seem to indicate that infection of the ova takes place by mass action of the organisms at the anterior pole of the egg. In this case a number of rather small oval bodies penetrate the egg, instead of a few elongated forms of the organism passing from the nurse cells to the egg with the nutriative material. (Plate 15, figures 10 and 11).

The organisms were occasionally found in the developing embryos within the mother, and were always found in the advanced embryos in the sectioned eggs, as well as in the newly hatched insects. (Plate 14 fig. 4). A critical study of this phenomenon in all stages of the insect has not been conducted, and consequently it must be passed without discussion. However, such a study is in progress, and it can be safely mentioned that the organisms in the young embryo multiply very rapidly until the maturity of the insect, at which time their number is considerably reduced, and that each individual is provided with its quota of these organisms upon hatching from the egg.

SYSTEMATIC POSITION OF THE ORGANISM

A careful comparative study of the organism found in *Saissetia oleae* (Bernard) with those reported from other scale insects shows that it closely approaches *Lecaniocola inglisiae* Brain found in *Inglisia geranii* Brain. Yet, it has some resemblance to *Lecaniocola filippae* Brain found in *Filippa chilianthi* Brain. It resembles the first form by its internal structure, while in the external morphology it approaches the second form. So far as measurements are concerned it is neither. Considering the above mentioned facts it is believed to be a distinct form and is described here as a new species.

Lecaniocola saissetiae sp. nov.

(Plate 15, fig. 5–9)

General form of the organism elongate, varying greatly in size and shape, commonly spindle shaped, sometimes pear or egg shaped, rarely spherical. Usually pointed at one end, often with a long narrow neck, the other end being rounded. Sometimes both ends are pointed. Protoplasm coarse, conspicuously granular, highly vacuolated, having from 2 to 4 or more large and a few smaller vacuoles, with a few minute highly refractive bodies. Multiplication by terminal budding at the pointed end; sometimes buds are formed on both ends. Buds may be spherical at first and later become oval or spindle shaped. More often the bud is produced as an oval swelling at the end of the elongated neck. Separation of buds in hanging drop cultures of normal salt solution takes place between 24 and 48 hours. More rarely the buds persist until fully grown. Only one or two, rarely three, terminal buds observed in a chain. Average size of typical mature organisms about 13 to 14μ long and 3.5μ broad. Average size of the newly separated individuals 6.5 to 7μ long and 3 to 3.5μ broad. Average size for small, egg shaped forms 3 to 5μ long. Chains of two or three buds often reach 26.5μ in length. The width varies from 2.5 to 4μ, the usual average being 3.5μ. The width of the neck varies between 1 and 2μ.

Organism found in the connective fat tissue and free in haemolymph of *Saissetia oleae* (Bernard).

FUNCTION OF THE ORGANISMS

The exact function of the symbiotic fungi or mycetozoa is not clearly understood. Their relation to the insects within which they gain shelter is believed to be symbiotic in nature. The benefit derived by the micro-organism is apparent. It enjoys protection and abundance of food. Several benefits may be suggested as being derived by the insect from the presence of these organisms. The most logical one is that of assisting in breaking down the fat tissue and assimilation of nutriative materials by some enzyme action during the formation of ova and embryonic development of the insects. The fact that the number of organisms is reduced within the mature insect after the formation of ova, at which time most of the fat tissue is utilized, is strongly in favor of that view.

The fact that every egg has symbiotic organisms within its embryo indicates that they must play an important role within the insect. It is quite possible that the organisms play an essential and yet some unknown part in the rapid development of the embryos within the eggs of this insect. The males of this species of scale insect are usually rare, and it is generally assumed that the insect reproduces parthenogenetically, at least in part. It is quite possible, in the light of the demonstration by Loeb, 1912, of the possibility of artificial fertilization of eggs of lower animals, that these yeast-like organisms are instrumental in initiating the embryonic development of parthenogenetic ova by enzymic stimuli or by the combination of physical, chemical and metabolic activities of organisms within the insect and its eggs.

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EXPLANATION OF PLATES

PLATE 13

FIG. 1. Photomicrograph taken from smear, showing yeast-like bodies from fat tissue of *Saissetia oleae* (Bernard).

FIG. 2. Photomicrograph of a 6μ section, showing the distribution of symbionts in situ of adipose tissue of a mature scale insect.

PLATE 14

FIG. 3. Photomicrograph of a longitudinal section through the egg within the insect, showing the yeast-like symbionts penetrating the ovum.

FIG. 4. Photomicrograph of a 6μ section through the young embryo within the egg of the insect, showing the presence and multiplication of yeast-like symbionts therein.

PLATE 15

FIG. 5. Yeast-like body, *Lecaniocola saissetiae* n. sp. with elongation at one pole, preparatory for budding.

FIG. 6. Formation of bud at the pointed pole.

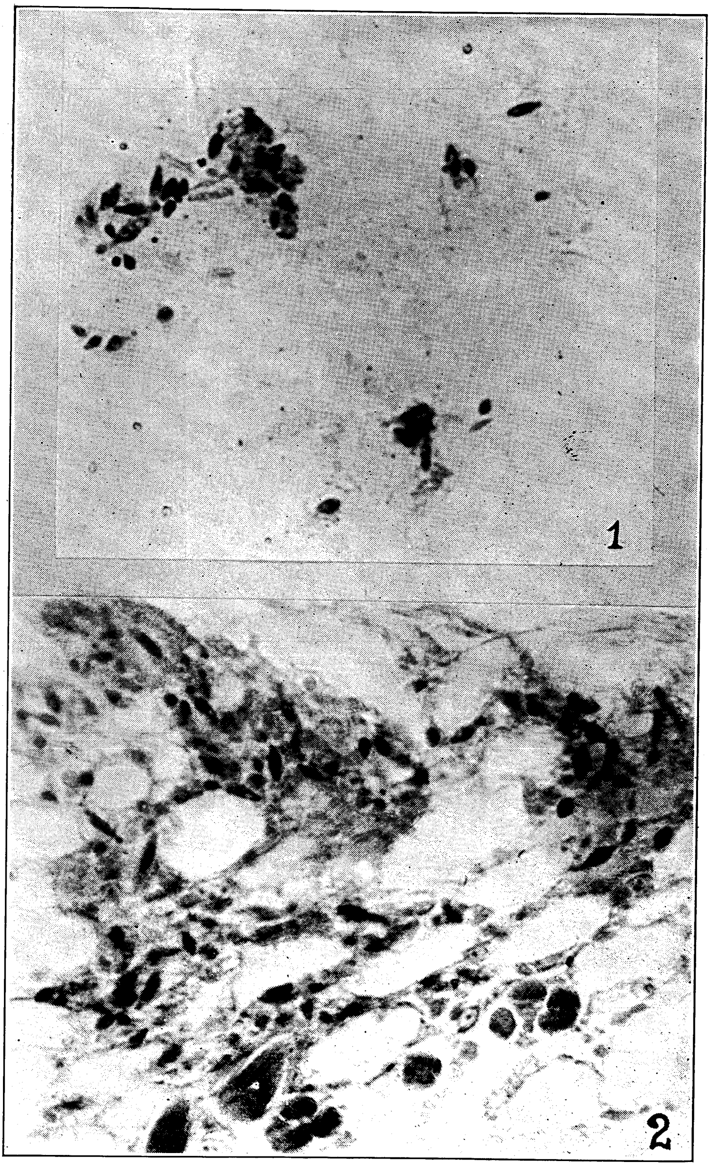
FIG. 7. Formation of buds on both poles.

FIG. 8. The bud at the pointed pole is about to separate from the mother organism.

FIG. 9. A newly separated yeast-like cell, showing tendency to form a bud soon after separation.

FIG. 10. Penetration of ovum by means of mass attack of yeast-like organisms.

FIG. 11. A single organism penetrated ovum through the nurse cell.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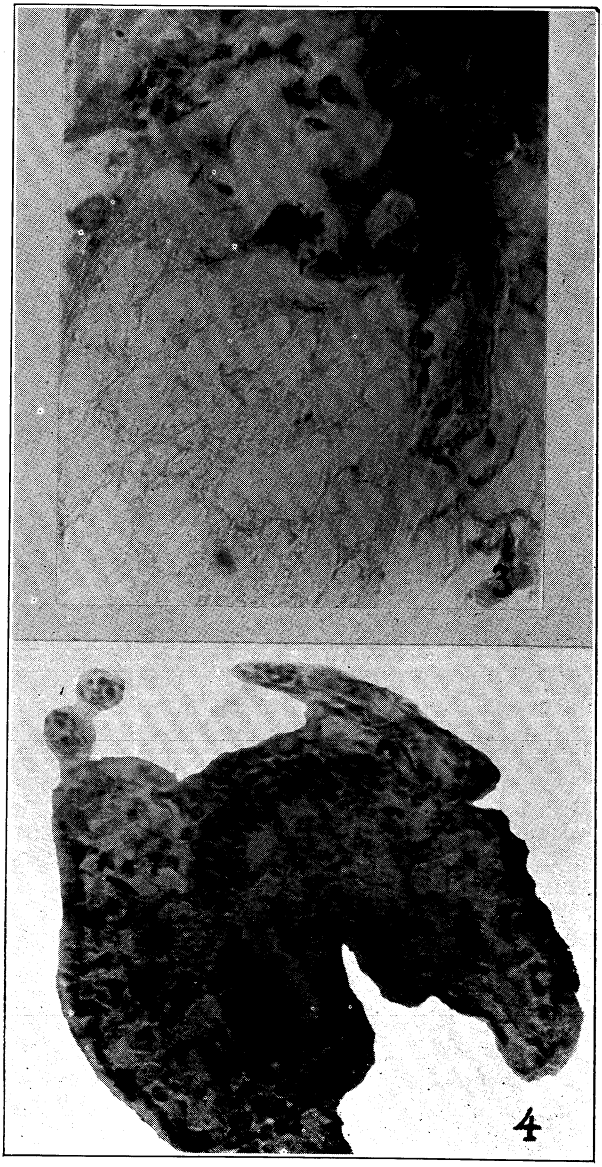
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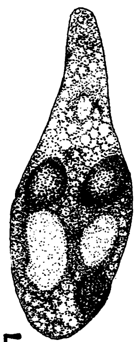

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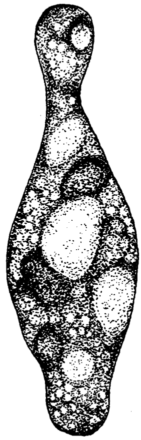

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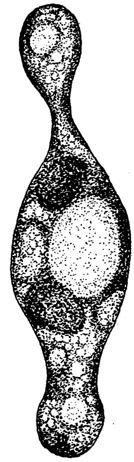

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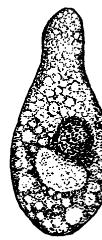

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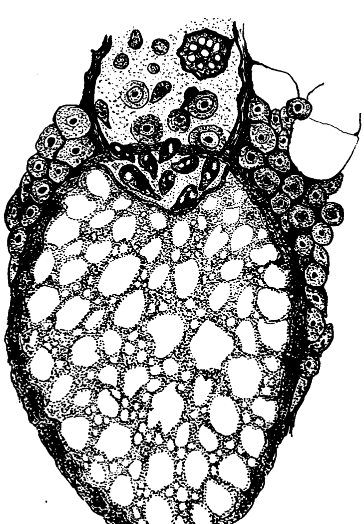

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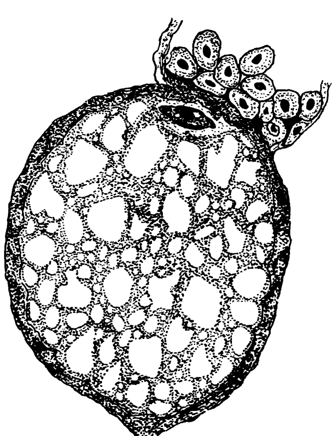

11

THE BIRDS OF DANE COUNTY, WISCONSIN

A. W. SCHORGER

Most of Wisconsin remains virgin territory from the standpoint of ornithology. Except for the Koshkonong region east to Racine and along the Michigan shore to Green Bay, very few comprehensive observations covering a period of years have been made. The avifauna of a given area usually changes greatly in the course of time. Some species become extinct or rare, while others change the route of their migration. It is a source of great regret that the Madison region should have had so little of its bird history recorded, especially since many of its earlier residents were qualified to leave data that would be invaluable at this time. The Golden Plover, though once common, no longer migrates through the state. There are no published records for the county. Correspondence and conversations with the oldest hunters failed to afford proof of their former presence; hence, that the Golden Plover visited Dane County is only a reasonable assumption.

The advance or retreat of a species is always of interest. Allan W. Carpenter[1], in 1892, found the Vesper Sparrow and Indigo Bunting to be rare summer residents at Madison. During the last 20 years, at least, they have been common. Within this period also the Cardinal and Tufted Titmouse have become permanent residents, and the Western Meadowlark a common summer bird.

It was decided to confine the present list of birds almost entirely to Dane County. This may appear arbitrary in view of the extensive work of the Kumliens on Lake Koshkonong, a small area of which lies within our limits. The fact that all the Kumlien skins examined were labelled Jefferson County had no bearing on this decision. Brewster has stated rightly "that all arbitrary boundaries established merely for convenience, should be regarded as more or less

[1] Cited by Lynds Jones, Wilson Quart. 4, No. 1 (1892) 28 and 34.

flexible." The main purpose has been to give a picture of the bird life as it has existed during the past fifteen years and relatively little work has been done on Lake Koshkonong during that time. In addition, an attempt has been made to rescue data on certain extinct species such as the Passenger Pigeon before it is too late.

PHYSIOGRAPHY

Dane County is located centrally in the southern portion of the state and is 24 miles from the Illinois line. Were it not for the intersection of the northwest corner by the Wisconsin River, the county would be an almost perfect rectangle. The distance from north to south is 30 miles, and from east to west 42 miles. Of the total area of 1,238 square miles, only 120 square miles bordering the Wisconsin River fail to lie within the drainage area of the Rock River basin.

Nature has endowed the county generously with those features conducive to the presence of a great variety and abundance of birds. Four of the largest lakes, Kegonsa, Waubesa, Monona, and Mendota, have a combined area of 28.7 square miles. The waters of these lakes run through the Yahara River into the Rock River. This system forms a great highway for waterfowl. In spring the line of flight passes over the chain of lakes north to the Wisconsin River that contributes its quota of migrants from the south and southwest. The Wisconsin River route is favored particularly by geese on account of the extensive sand flats in its wide and usually shallow bed, and Lake Wisconsin where the birds can rest in safety. Adjacent level cornfields are used as feeding grounds.

The western portion, approximately one-third of the county, lies in the driftless or non-glaciated area. The line bounding this area enters the county at Sauk City, passes between Black Earth and Cross Plains in a slightly southeastern direction, and leaves the county near Belleville. This portion of the county is a succession of high hills and contains the most extensive tracts of woodland. The Sauk County shore of the river has a high bluff, where the Duck Hawk breeds and raids the adjacent lowlands of Dane

County. Here are extensive sandy wastes where the Lark Sparrow occurs, extensive marshes, and large timber areas that are unique in their number of the rarer birds. The rolling country of the central and eastern portion of the county contains most of the lakes and marshes.

PRINCIPAL TREES

With the exception of the prairie that was limited to the watershed, and naturally the lakes and marshes, the county was formerly well timbered. Oaks predominate still, the most abundant species being the white oak (*Quercus alba* Linn.), scarlet oak (*Q. coccinea* Muench.), and red oak (*Q. rubra* Linn.) Indigenous gymnosperms, with the exception of the tamarack (*Larix laricinia* Koch) of the swamps, are relatively scarce. A few black spruce (*Picea mariana* B. S. P.) are to be found at Hook Lake, and scattering white pines (*Pinus strobus* Linn.) at Pine Bluff, and other places in the western portion of the county. The red juniper (*Juniperus virginiana* Linn.) is not uncommon, particularly near the Wisconsin River. Boreal birds, however, find such cultivated species as Norway spruce (*Picea excelsa* Link.), and European larch (*Larix europea* D. C.) to their liking. The Redpolls, Crossbills, and Pine Grosbeaks prefer the cones of the European larch to all the others.

The following additional hardwoods are common:

Bur oak (*Quercus macrocarpa* Michx.)
Glaucous willow (*Salix discolor* Muehl.)
Hoary willow (*Salix candida* Flügge)
Aspen (*Populus tremuloides* Michx.)
Large-toothed aspen (*Populus grandidentata* Michx.)
Basswood (*Tilia americana* Linn.)
Sugar maple (*Acer saccharum* Marsh.)
Silver maple (*Acer saccharinum* Linn.)
Box elder (*Acer negundo* Linn.)
Locust (*Robinia pseudacacia* Linn.)
Wild plum (*Prunus americana* Marsh.)
Choke cherry (*Prunus virginiana* Linn.)
Black cherry (*Prunus serotina* Ehrh.)
Serviceberry (*Amelanchier canadensis* Linn.)
White ash (*Fraxinus americana* Linn.)

Black ash (*Fraxinus nigra* Marsh.)
White elm (*Ulmus americana* Linn.)
Butternut (*Juglans cinera* Linn.)
Black walnut (*Juglans nigra* Linn.)
Shag-bark hickory (*Hicoria ovata* Britton.)
Bitternut (*Hicoria minima* Britton.)

The following vines and shrubs are an important source of fruits upon which birds feed:

Wild red raspberry (*Rubus strigosus* Michx.)
Black raspberry (*Rubus occidentalis* Linn.)
Dewberry (*Rubus* sp.)
Blackberry (*Rubus* sp.)
Prickly gooseberry (*Ribes cynosbati* Linn.)
Missouri gooseberry (*Ribes gracile* Michx.)
Wild black currant (*Ribes floridum* L'Her.)
Common elder (*Sambucus canadensis* Linn.)
Frost grape (*Vitis riparia* Michx.)
Virginia creeper (*Psedera quinquefolia* Greene)
Climbing bitter-sweet (*Celastrus scandens* Linn.)
Poison ivy (*Rhus toxicodendron* Linn.)

Life Zones

The county lies in the Alleghanian Area of the Transition Zone with the exception of a narrow strip bordering the Wisconsin River that it is unquestionably in the Carolinian Area of the Upper Austral Zone. The division is based on the avifauna which on account of its mobility always extends beyond the plants peculiar to a given zone. Of the trees characteristic of the Carolinian Area, sassafras, tulip tree, hackberry, sycamore, sweet gum, rose magnolia, red bud, and persimmon, all are absent from or excessively rare in the county with the exception of the hackberry. There is a single sycamore growing naturally at the edge of the water at Colladay Point, Lake Kegonsa, but this may have originated from the seed of introduced trees.

The following species of birds characteristic of the Carolinian Area breed in the Mazomanie region: Tufted Titmouse, Blue-gray Gnatcatcher, Cardinal, Kentucky Warbler, Louisiana Water Thrush, Blue-winged Warbler, Prothonotary Warbler, Yellow-breasted Chat, Red-bellied Woodpecker, and Red--shouldered Hawk.

Some of the trees common to the bottom lands are: river birch, white elm, silver maple, white ash, glaucous willow, prickly ash, bur oak, red oak, black oak, white oak, large-toothed aspen, basswood, red juniper, and hoary alder.

Seasonal Distribution of Birds

There are few birds that do not migrate to some extent during the year. Certain species such as the Blue Jay and Red-headed Woodpecker winter regularly, but the numbers remaining represent but a fraction of the summer residents.

Permanent Residents.

- Black Duck
- Red-tailed Hawk
- Ruffed Grouse
- Prairie Chicken
- Bob-white
- Ring-necked Pheasant
- Barn Owl
- Screech Owl
- Great-horned Owl
- Barred Owl
- Long-eared Owl
- Short-eared Owl
- Pileated Woodpecker
- Red-bellied Woodpecker
- Red-headed Woodpecker
- Hairy Woodpecker
- Downy Woodpecker
- Blue Jay
- Crow
- Tufted Titmouse
- Chickadee
- White-breasted Nuthatch
- Starling
- Cardinal
- English Sparrow
- American Goldfinch

Irregular Winter Visitors from the Boreal Region.

- Goshawk
- Snowy Owl
- Saw-whet Owl
- Horned Lark
- Bohemian Waxwing
- Northern Shrike
- Evening Grosbeak
- Pine Grosbeak
- Redpoll
- Pine Siskin
- American Crossbill
- White-winged Crossbill
- Snow Bunting

Summer Residents Occasionally Wintering.

- Mallard
- Cooper's Hawk
- Marsh Hawk
- Sparrow Hawk
- Brown Thrasher
- Robin
- Bluebird
- Cedar Waxwing

Coot
Mourning Dove
Flicker
Prairie Horned Lark
Prairie Marsh Wren
Meadowlark
Thick-billed Redwing
Cowbird
Song Sparrow

Birds Breeding to the Northward, but Migrating Regularly Southward in Fall, Occasionally Wintering.

Canada Goose
Golden-eye
Merganser
Rough-legged Hawk
Wilson's Snipe
Herring Gull
Yellow-bellied Sapsucker
Red-breasted Nuthatch
Brown Creeper
Winter Wren
Golden-crowned Kinglet
Rusty Blackbird
Purple Finch
Slate-colored Junco *
Tree Sparrow *
White-throated Sparrow
Lapland Longspur
* Winters regularly

ACKNOWLEDGMENTS

The data on migration are taken largely from the author's notes that were begun in 1910, and kept regularly from 1913 to the present time. Use has been made of the notes of the late Norman DeWitt Betts covering the years 1913 to 1916. Special recognition is given to Mr. Warner Taylor who, except during late summer and early autumn, has done extensive work in the field since 1913. Dr. Witmer Stone kindly provided the revised nomenclature and arrangement of species in advance of the appearance of the new check-list.

ANNOTATED LIST OF BIRDS

PART I

Family GAVIIDAE. Loons

1. *Gavia immer* (Brünnick). **Loon.** This species is a common migrant. Individuals in mature plumage are found frequently in summer but there are no recent breeding records. It appears shortly after the lakes open, the average date of arrival being April 3. In 1923, several were seen on March 11. It occurs in largest numbers dur-

ing the first two weeks of April and only an occasional bird is found after May 3.

In autumn, the Loon seldom arrives before the last week in October. The earliest date is Sept. 11, 1914. It is most common in November and has not been noted after December 1.

Family COLYMBIDAE. Grebes

2. *Colymbus holboelli* (Reinhardt). **Holboell's Grebe.** An uncommon migrant. One was seen April 28, 1922 by Mr. Warner Taylor[1]. Another was shot by a hunter on Lake Mendota, Nov. 15, 1925, and identified by Mr. Taylor[2] who gave the bird to me.

The skin is now in my collection.

3. *Colymbus auritus* Linnaeus. **Horned Grebe.** This handsome grebe is a common migrant. It is found occasionally in marshes, but usually on the large lakes, in small loose flocks. The average date of arrival is April 14; the earliest date April 5, 1925. The latest date of departure is May 14, 1917. The migration is usually completed before May 7.

The fall migrants appear October 15 and depart before December. The latest date is Nov. 28, 1920. This species frequently swims into duck decoys. If a flock takes fright and scatters, the birds utter a high-pitched collecting note, "pee-your, pee-your".

4. *Podilymbus podiceps* (Linnaeus). **Pied-billed Grebe.** An abundant summer resident. Scarcely a marsh with standing water or reedy pond lacks several breeding pairs. The average date of arrival is April 6, the earliest date being March 20 (Taylor). The fall migration is completed by Nov. 27. The latest date is Dec. 20, 1925. There is always the chance that an unusual date is due to a wounded bird.

Nests with eggs have been found from June 9 to 19. It is exceptional to find a nest the eggs of which have not been carefully covered with a mass of decayed vegetable matter by the departing bird.

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[1] Auk 40 (1923) 339.
[2] Auk 43 (1926) 250.

Family PELECANIDAE. Pelicans

5. *Pelecanus erythrorhynchos* Gmelin. **White Pelican.** The white pelican had become a rare migrant in southern Wisconsin by 1900. The route of migration is now mainly west of the Mississippi River. Five were seen over Lake Waubesa, April 22, 1925 by Warner Taylor[3]; and two were seen on Mud Lake April 15, 1926 by Dr. W. V. Bryant[4].

A white pelican was shot by Dr. Arthur G. Sullivan near the mouth of the Yahara River, Lake Mendota, the latter part of October in either 1917 or 1918. "This was a single bird that sat out on the sandbar the greater part of the day and flew north of Crescent Bog making a circle of the bay every thirty or forty minutes, and returning to the sandbar, which is west of Farwell's Point. Each time the bird passed over me my curiosity increased because I did not know that it was a pelican. Finally, on about the fourth or fifth excursion the bird made, I shot it."

Dr. S. H. Chase informed me that he remembers the pelican. Owing to destruction by fire of the record book of the Crescent Club, the date cannot be fixed more closely.

Family PHALACROCORACIDE. Cormorants

6. *Phalacrocorax auritus auritus* (Lesson). **Double-crested Cormorant.** There has been a marked increase in this species since 1920. Flocks numbering several hundred birds are now not uncommon. The habit of flying abreast in only slight V-formation produces an impressive black line against the sky. The birds arrive as early as April 2, and the height of the migration is reached the last week in the month. The earliest date of arrival is March 31, 1928 (Taylor). Final departure from the Madison lakes takes place May 15 to 18.

This species nested with Great Blue Herons at Okee in 1921, in the trees killed by the formation of Lake Wisconsin[5]. I found the herons nesting here in 1919, but there

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[3] Auk 43 (1926) 250.

[4] Schorger, Auk 43 (1926) 556.

[5] Stoddard, Yearbook Public Museum Milwaukee for 1921 (1922) 36; Shrosbree, Ibid. 28.

were no Cormorants present. A flock of 12 birds was seen on a pond at Springfield Corners, July 17, 1927.

The southward movement in fall takes place largely beyond our limits since relatively few Cormorants are to be seen. The extreme dates of arrival and departure are September 23, 1925 and November 15, 1922.

Family ARDEIDAE. Herons and Bitterns

7. *Ardea herodias herodias* Linnaeus. **Great Blue Heron.** Common summer resident, arriving on the average April 6. The earliest date of arrival is March 22, 1925. The latest fall record is October 25, 1919.

A heronry at Okee, Lake Wisconsin, contained 14 nests in 1919[6], and was occupied through 1921[7]. The nesting trees, standing in the water, have since been felled.

Most of the eggs are deposited the last two weeks in April. The period of incubation is about 28 days. Since the eggs at Okee began to hatch May 11, some of them must have been deposited before April 15.

8. *Casmerodius egretta* (Gmelin). **Egret.** Though formerly nesting in the state, the Egret is now only a rare straggler from the south. When found in southern Wisconsin, it is usually in August or September. One was seen May 30, 1925 at Mud Lake, near Waterloo, Jefferson County, by Warner Taylor[8]. The locality is only a few miles from the county line.

9. *Butorides virescens virescens* (Linnaeus). **Green Heron.** Common summer resident, arriving the first week in May. The earliest date is April 25 (Taylor). It has not been noted after September 30.

Nests with eggs have been found from May 19 to June 16. The birds usually nest apart but colonies are sometimes found. A colonial nesting site may be abandoned for no apparent reason and then reoccupied after an interval of one or more years. The condition of a group of six nests found in an oak thicket on June 5 was: one nest with 5 eggs; one with 6 eggs; two with 3 eggs and 2 young;

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[6] Schorger, Auk 37 (1920) 143.
[7] Stoddard, *vide supra.*
[8] Auk 43 (1926) 250.

one with one egg and 3 young; and one with 4 eggs and 1 young. Trees near creeks and ponds are preferred as nesting sites.

10. *Nycticorax nycticorax naevius* (Boddaert). **Black-crowned Night Heron.** The "Quak" of this heron flying to its feeding grounds is a familiar night sound. Owing to its crepuscular and nocturnal habits, it may be overlooked in regions where it is common. Except during the breeding season, the day is usually spent in trees or in the midst of rushes. The first migrants arrive March 20 (Taylor) to April 15. It has not been noted in fall after September 30. The birds separate following the nesting season and are widely distributed from July 15 to September 1. A thriving colony has existed in a woods near Cooksville for several years. The eggs are deposited mainly between May 15 and 30, and the period of incubation is 24 to 26 days.

11. *Botaurus lentiginosus* (Montagu). **Bittern.** Common summer resident. The generic name of this bird is obscurely descriptive of its notes, and is perpetuated in the vernacular by "Bog-Bull". Certainly for the American species the notes resemble far more the sound of the old fashioned wooden pump than the bellowing of a bull. The average date of arrival is April 16. My earliest record is April 9, though Bent[9] gives March 30. The latest date of departure is October 28, 1923.

A nest found June 27, contained one addled egg and 2 small young. As soon as I approached, the young "hissed" and crept slowly through the vegetation, where in a frozen position they were very difficult to distinguish. Another sound produced by clicking the mandibles together was accompanied by pronounced distention of the chin.

12. *Ixobrychus exilis* (Gmelin). **Least Bittern.** On the basis of "intelligence" this species should be placed at the foot of the bird class. One allowed my dog to take it alive under inexcusable circumstances. The average date of arrival is May 18; the earliest May 10, 1914 (Betts). The latest date of departure is September 23.

The nests are almost invariably placed on a platform of

[9] North American Marsh Birds, Bull. 135, U. S. Nat. Museum, p. 83.

cat-tails. I have not found full sets of eggs before June 1. On June 13, 1914, I examined sixteen nests in an area of two acres. Seven contained 6 eggs, seven 5 eggs, and two 4 eggs each.

Family ANATIDAE. Swans, Geese, Ducks

13. *Cygnus columbianus* (Ord.) **Whistling Swan.** This handsome bird is an uncommon migrant and has been accorded full protection by law to save it from extermination. There are the following spring records: 6 seen on Lake Mendota, April 5, 1925 by Taylor[10]; 4 on Lake Kegonsa, April 10, 1926, and 40 on the following day by Dr. W. V. Bryant; 7 on April 23, 1926 by Dr. S. H. Chase[11]; and 3 on Lake Mendota March 27, 1927 by the writer.

The fall records consist of 7 seen on Lake Mendota October 23, 1925; and an immature bird shot for a goose by a Madison hunter Nov. 18, 1926. The latter bird was identified by John Main.

14. *Branta canadensis canadensis* (Linnaeus). **Canada Goose.** Common migrant, exceeding greatly in number all other species of geese. This hardy bird is a not uncommon winter resident, especially on the Sauk prairie. The earliest date of arrival in spring is March 6, the average date being March 16. All have departed by April 18. The Wisconsin River is the great resting place during the spring migration, and on Lake Wisconsin "literally thousands" of Canada Geese can be seen.[12]. The fall migration takes place with great regularity. During eight of sixteen years' observations, the first migrants appeared between October 19 and 24. The southward movement is practically completed by November 15.

15. *Chen hyperboreus hyperboreus* (Pallas). **Snow Goose.** The records for the Snow Goose are meager, and probably misleading as to its numbers. The indications are that the great majority of these geese pass through the county without stopping. Gromme[13] observed a heavy

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[10] Auk 43 (1926) 250.
[11] Schorger, Auk 43 (1926) 556.
[12] Stoddard, Yearbook Public Museum, Milwaukee for 1921 (1922) 36.
[13] Auk 44 (1927) 96.

flight over Lake Winnebago November 1, 1926. Stragglers are occasionally reported by hunters as occurring in flocks of Canada Geese along the Wisconsin River. I found a lone Snow Goose on the shore of Lake Kegonsa, May 5, 1928. This bird, in sound condition, was shot the following day by John Main. The skin is in my collection.

There is only a remote chance for the occurrence of the Greater Snow Goose (*Chen hyperboreus nivalis*), there being but one good record for the interior.[14]

16. *Chen caerulescens* (Linnaeus). **Blue Goose.** Rare migrant. The only record is a flock of 40 observed over Lake Mendota by John Gundlach, December 10, 1927.

17. *Anas platyrhynchos platyrhynchos* Linnaeus. **Mallard.** Abundant migrant and common summer resident. This hardy bird occasionally winters. It pushes northward in spring as rapidly as water becomes available. The earliest record is March 5, 1921; average date of arrival March 19. The fall flight is at its height the last two weeks of October.

During August the young and old birds congregate in favorite marshes, as many as one hundred having been seen together. The wariness of the Mallard permits it to survive in breeding grounds from which other species have long since vanished.

18. *Anas rubripes tristis* Brewster. **Black Duck.** When Brewster in 1902 described the Red-legged Black Duck (*Anas rubripes rubripes*), he started a discussion on the validity of a species upon which experts have continued to disagree. *Rubripes* has bright coral red legs and toes, in contrast with the yellow or orange-yellow of *tristis,* and presumably occupies a boreal region north of the range of *tristis.* Bent[15] considers *rubripes* as the more hardy, mature Black Duck.

The species breeding locally is unquestionably *tristis* while *rubripes* may be sought among the late fall migrants and wintering birds. Local hunters recognize the following: up to the middle of October the ducks shot have greenish brown to yellow legs; there follows a hiatus of

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[14] Bent, Bull. 130 U. S. Nat. Mus. (1925) 173.
[15] Bull. 126 U. S. Nat. Mus. (1923) 64.

about a week, then from October 25 to November 20, or as long as the marshes are open, the ducks shot are larger and have orange legs. Personally, I have never seen a specimen in the flesh that could be referred to *rubripes.* The latest date on which I have shot a Black Duck is November 10, and the legs of this bird were bright yellow.

The Black Duck arrives in spring simultaneously with the Mallard and does not depart in fall until the marshes are frozen. A few winter regularly where the Yahara River remains open. Flocks of 25 to 30 birds are common in August. Mallards and Black Ducks intermingle while feeding, but when flushed there is segregation according to species.

19. *Chaulelasmus streperus* (Linnaeus). **Gadwall.** Though formerly common, the Gadwall has become one of the rarest of the native marsh ducks. It has been observed in spring from March 27 to May 10, and in fall from September 3 to October 18. Taylor[16] saw four October 19, 1922. The average date of arrival in spring is April 13.

20. *Mareca penelope* (Linnaeus). **European Widgeon.** While a rare species, the American records are too numerous to consider the European Widgeon a straggler. It has probably become established as a breeding species. It has been noted on three occasions at Madison in spring only as follows: April 22, 1917, and April 3, 1927[17]; April 14, 1918.[18] This species associates in migration with the Baldpate to which it is closely related.

21. *Mareca americana* (Gmelin). **Baldpate.** The Baldpate is an early migrant, the average date of arrival being March 19. The earliest record is March 12, 1922. The fall migration lasts from Sept. 30 to Nov. 27. The Baldpate formerly bred in southern Wisconsin, but is now known only as a transient.

22. *Dafila acuta tzitzihoa* (Vieillot). **Pintail.** The sight of a flock of Pintails flying low over a marsh on a March morning renders the observer oblivious to chilling winds. The long neck, long tail, and white underparts of the male produce the mirage of a frigate under full sail.

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[16] Auk 40 (1923) 339.
[17] Schorger, Auk 35 (1918) 74; ibid. 45 (1928) 106.
[18] Taylor, Auk 36 (1919) 277.

This species arrives March 12 and is common by the last week of the month. Most of the birds have departed by April 15, but the occurrence of mated pairs is not uncommon up to the last week in May. This fact coupled with the presence of mature birds in August is the only evidence that the Pintail may breed, as formerly, in this region. Inclusive dates for the fall migration are Sept. 24 and Nov. 13.

23. *Nettion carolinense* (Gmelin). **Green-winged Teal.** This handsome teal arrives as early as March 18 and is most common during the first week in April. It has not been observed after April 23. The fall migration lasts from Sept. 16 to Oct. 22. One spent the winter of 1928–9 with the Mallards kept by Prof. J. G. Dickson at the Nakoma spring.

The flight of the Green-winged Teal is singularly swift and erratic. When in good form, the evolutions performed will take the conceit from any except the best shots. I have had them appear suddenly over the decoys, do a figure eight, and be gone so swiftly as to leave me with a cold gun.

24. *Querquedula discors* (Linnaeus). **Blue-winged Teal.** This species is a later migrant than the Green-winged Teal. Though it has been noted by March 25, the average date of arrival is April 9. The period of greatest abundance is April 23 to May 1. It has not been noted after October 27.

The Blue-winged Teal shares with the Mallard and Black Duck the distinction of nesting regularly in the county. Records: May 17, 6 eggs; May 28, 7 eggs; and July 2, a nest with 10 eggs, 9 of which were hatched on July 12. The three nests examined were on high ground 50 to 600 feet from the water in the marsh. Cattle, aside from natural enemies, are destructive to nests by trampling.

25. *Spatula clypeata* (Linnaeus). **Shoveller.** In 1921 and 1922 this species arrived March 12. Normally, the first migrants appear March 27 to April 8, and the species is common until May 26. The latest fall record is Oct. 16. A female with six half-grown young was seen July 18, 1925. The Shoveller probably breeds more frequently than this single record indicates.

26. *Aix sponsa* (Linnaeus). **Wood Duck.** This duck is the loveliest of all our waterfowl. The accompanying at-

FIG. 1. Nest of Bluewinged Teal.

FIG. 2. Nest of Virginia Rail.

FIG. 3. Nest of Coot.

FIG. 4. Nest of Least Bittern.

tributes of gentleness and confidence in man led it far on the road to extermination. It is gradually increasing in numbers, though still one of our rarer species. The migration dates are so few as to be subject to considerable revision as further data accumulate. It has not been noted in the Madison region before April 29, though it may be looked for the last of March. The average date of arrival at Heron Lake, Minnesota is April 4. The species is occasionally found in the marshes around Madison in August, and occurs in greatest numbers during September and the first week in October.

The Wood Duck has received the protection of the law but many are shot unwittingly by hunters in the dim light of early morning. This is especially true of the first day of the hunting season when these ducks are entirely unsuspicious. On the morning of September 16, 1922, I was at Mud Lake, Columbia County, a few miles from the Dane County line. Twenty Wood Ducks were seen, six of which were dead birds left on the water where they fell. This useless destruction is a difficult problem with which to cope. On July 11, 1926, 13 old Wood Ducks and 6 small young were seen on the same pond. It undoubtedly nests sparingly in Dane County.

27. *Nyroca marila* (Linnaeus). **Scaup Duck.** This species is a regular migrant on the large lakes, but is decidedly less numerous than its smaller relative. Judging from sight records and the bags of hunters, there is one *marila* to fifty *affinis*. Hollister[19] has recorded the number of ducks killed by his party, at Delavan Lake, from the fall of 1892 until the fall of 1899. During this period there were 20 Scaup and 182 Lesser Scaup obtained.

I was in a blind on Lake Kegonsa, Nov. 13, 1927, when one Scaup was shot out of a flock of twenty. It arrives in spring from March 12 to 25.

28. *Nyroca affinis* (Eyton). **Lesser Scaup Duck.** This is the most abundant species of ducks. Rafts of 100 to 600 birds are not uncommon. It decoys readily and is killed in large numbers. The average date of spring arrival is March 20; the earliest March 5. It is common until the

[19] Auk 37 (1920) 367.

middle of May and the last stragglers, probably non-breeding birds, do not depart until May 22.

Fall migrants appear Oct. 20, and are abundant throughout November. The final departure is regulated by the freezing of the lakes. During the winter of 1913–1914, they remained until Jan. 10.

29. *Nyroca collaris* (Donovan). **Ring-necked Duck.** This is a common migrant. It associates with the Lesser Scaup, and their migrations are coeval. In the spring, both species are found commonly on small ponds and flooded marshes; but in fall their activities are confined mostly to the larger lakes where like the other sea ducks they dive to considerable depths for aquatic plants.

30. *Nyroca americana* (Eyton). **Redhead.** Though formerly abundant, the Redhead is no longer common. Flocks greater than twenty to thirty birds are seldom seen. This species occurs usually in small numbers intermingled with the Lesser Scaup. It arrives as soon as the lakes show open water, the earliest date being March 11. Nearly all have departed by the last week of April, the latest date being May 14. The fall migration begins Oct. 5 and ends on the closing of the lakes.

The decrease of this species is due to its being an excellent table bird and to the fact that on certain days it will decoy with ridiculous ease.

31. *Nyroca valisineria* (Wilson). **Canvasback.** The Canvasback with its Hanoverian profile is the aristocrat of the duck family. While praised by epicures, it is in fact no better in taste than the other members of the genus Nyroca. This species attains large size. A male weighing 1648 grams was shot at Fox Lake, Nov. 8, 1928.

The average date of arrival in spring is March 18; the earliest March 10, 1927. Most of the birds have departed for the north by April 20, but stragglers have been noted up to May 11. The fall migrants appear the middle of October and remain in large numbers until the lakes freeze. On January 10, 1914 there was a raft of 2000 Canvasback on Lake Mendota between Picnic and Second Points.

It is gratifying to state that this fine bird appears to be maintaining its numerical strength. Rafts of several hundred birds are common. This species loves to take to the air on bright days. About 10 o'clock in the morning and again at 3 o'clock in the afternoon all the Canvasback leave the water and go "on parade". There is nothing more inspiring than the sight of flock after flock of these powerful birds sweeping along the shore of the lake. The first arrivals decoy quite readily, but they soon become so wary that flocks numbering more than a few birds will seldom come in.

The Canvasback secures its food from the bottom of the lake, hence is an expert diver. It is practically useless to pursue a winged bird if the water is at all rough. After swimming beneath the surface for a considerable distance, the bird rises for air but only the bill appears above water. The Canvasback is reputed to feed largely on eel grass or "wild celery" (*Vallisneria spiralis* Linn.). Stomachs of birds shot at Fox Lake, Lake Mendota, and Lake Kegonsa were filled largely with the propagating buds of this plant. At Lake Koshkonong, however, Mr. H. L. Skavlem[20] found that 60 to 80 per cent of the food consumed consisted of the buds of the pond-weed *Potamogeton pectinatus* Linn. He further states that the Canvasback is comparatively indifferent to wild celery.

The above plants form a large portion of the aquatic vegetation of Lake Mendota.[21] Canvasback use Lake Mendota year after year. Lakes Kegonsa, Waubesa, and Monona follow in their order. In some years this species is common on Lake Kegonsa, and again as in the fall of 1928, very few birds are present. The effect on the food supply of seining for carp has never been satisfactorily determined. The Canvasback nests rarely in this county. Prof. J. G. Dickson informs us that in June, 1927, a pair had a nest with nine eggs near the Nakoma spring. Eight of the eggs hatched and seven of the birds survived. In 1929, a pair was seen frequently in Hammersley Marsh up to May 24.

32. *Glaucionetta clangula americana* Bonaparte. **Golden-eye.** Common migrant. A few always winter where the creeks and springs provide open water. Hunters com-

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[20] Bull. Wis. Nat. Hist. Soc. 3 (1905) 168.

[21] Rickett, "A quantitative study of the larger aquatic plants of Lake Mendota". Wis. Acad. Sci. 20 (1922) 501–527.

monly call it Winter Duck or Whistler. The Golden-eye arrives early in March, the average date being the 11th. The earliest date is March 2, 1924 when ten were seen. The birds depart the second week in April and only a few are found after the 18th. The southward movement in fall seems to be controlled by the freezing of the northern lakes. It arrives in the Madison region from Nov. 4 to 16, and remains until the lakes close.

The Golden-eye has a restless disposition and seems to spend as much time in the air as on the water. It is not gregarious, except when forced to become so by limited open water. I have never seen more than 40 of this species in one flock when the lakes were open, and this number is exceptional. Ordinarily less than a dozen birds are seen together. It does not decoy easily.

33. *Charitonetta albeola* (Linnaeus). **Buffle-head.** This handsome little duck is a regular migrant. It has decreased so greatly that in point of numbers it is scarcely more common than the Wood Duck. Protection from shooting should be provided for a period of years. It is ordinarily found in pairs, flocks of 8 to 12 birds being the exception. It decoys easily for the hunter by whom it is known as "Butter-ball".

The Buffle-head is found in spring from March 22 to April 25 and in fall from October 9 until the lakes close.

34. *Clangula hyemalis* (Linnaeus). **Old-squaw.** This hardy northern duck is decidedly uncommon away from Lake Michigan. It is difficult now to accept the statement of Kumlien and Hollister[22] that this species is "anything but rare on most of the larger lakes". Of the 1167 ducks killed at Delavan Lake from 1892 to 1899, only 8 were Old-squaw.[23]

One was flushed from a spring at Lake Wingra, Jan. 19, 1913.[24] Mr. John Gundlach informs me that one was observed daily on Lake Mendota from April 5 to 13, 1925.

On March 2, 1929, Prof. J. G. Dickson found a male Old-squaw in the lagoon of the Nakoma Golf Club. The

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[22] Birds of Wisconsin, Wis. Nat. Hist. Soc. 3 (1903) 25.
[23] Hollister, l. c.
[24] Schorger, Auk 43 (1926) 556.

bird was very unsuspicious and was photographed at close range.

35. *Melanitta deglandi* Bonaparte. **White-winged Scoter.** In view of the breeding of this species in North Dakota and the Canadian prairie provinces, the White-winged Scoter might be expected to occur regularly in Dane County. The records as a matter of fact are few, for we seem to be on the edge of the path of migration. The movement of these ducks from the above breeding grounds is by way of the Great Lakes, where it winters commonly, to the New England coast, and vice versa.

There are no spring records. I shot a pair at Picnic Point, Lake Mendota, Oct. 30, 1910.[25] Decoys appear to be irresistible. On Nov. 20, 1927, I happened to stop at a blind on Lake Mendota when three White-winged Scoters came in to the decoys and escaped a fusillade unscathed. After flying half a mile, one bird turned back, alighted among the decoys and was killed. Taylor[26] saw one Dec. 3, 1922.

The White-winged Scoter feeds preferably on shellfish and its flesh is not a delicacy. The feathers are so firmly attached that it is preferable for the mildly religious to begin by skinning rather than plucking.

36. *Erismatura jamaicensis rubida* (Wilson). **Ruddy Duck.** Migrant in small numbers. It usually arrives from April 1 to 15, and has stayed until May 10. April is the accepted month for its arrival in the northern states though Eaton [27] gives March 10 to 20 for New York. My earliest record is March 15, 1914. The notes of Norman De Witt Betts give three occurrences for this month: March 30, 1913; March 14, 1914; March 31, 1916. The southward movement takes place in October. I shot one from a flock of four flying low over the Widespread, Oct. 16, 1910. It has not been noted after Nov. 13.

We are within the breeding range of the Ruddy Duck and it may nest occasionally. An adult male was seen on a pond near Verona July 16, 1927.

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[25] Auk 43 (1926) 556.
[26] Auk, 43 (1926) 250.
[27] "Birds of New York" 1 (1910) 226.

37. *Lophodytes cucullatus* (Linnaeus). **Hooded Merganser.** This Merganser is still a common migrant, but its numbers have decreased greatly. Of the ducks killed at Delavan Lake from 1892 to 1899, 13.4 per cent were Hooded Mergansers.[28] This percentage would not obtain today. The male is a handsome bird and is seen at his best during the spring courtship. One moment the head with depressed crest rests on the breast; the next, the neck is outstretched and the white crest outlined in black flashes forth. It prefers swamps, streams, and ponds to the large lakes. Its flesh is barely palatable, but since it decoys readily, few hunters resist the temptation to burn their powder.

This species arrives the middle of March (March 13, 1927), and is most common the first week in April. It has remained until May 6. It is a late fall migrant. It arrives in November and remains until the lakes close. The earliest record is a female shot November 6.

There are two summer occcurrences. Two were seen on one of the Verona ponds July 16 and 17, 1927. They were feeding on small bull-heads *(Amiurus)* which were swallowed without difficulty. Betts saw one June 28, 1914.

38. *Mergus americanus* Cassin. **Merganser.** The sight of the handsome male Mergansers uttering their hoarse "kwerr" as they fly from one patch of open water to another renders one an easy victim to the belief that spring is not "far behind". This species is a powerful flyer and expert diver. Its flight is so loon-like as to be deceptive at a distance. It is sometimes shot over decoys placed on a point, but this is due I believe to the directness of its flight. I have never seen one show indications of having been influenced by them. The hardy Merganser occasionally winters and pushes northward in spring ahead of all the other wild fowl; hence it is difficult to state when migration begins. The males arrive first. Mud Lake and the Yahara River between Lakes Monona and Waubesa are favored localities. At the latter place I counted 125 on February 15, 1925. Rafts of 100 to 300 are to be found from March 11 to 21. They leave correspondingly early

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[28] Hollister, Auk 37 (1920) 369.

and are seldom seen after the middle of April. In fall they appear by October 21 and remain until the lakes freeze. At this season they do not collect in large flocks.

39. *Mergus serrator* Linnaeus. **Red-breasted Merganser.** Common migrant, more numerous than *L. cucullatus* but less so than *M. americanus.* Occurs in spring from March 12 to April 25. It is most abundant from April 8 to 20. It arrives in the fall Nov. 13 and remains until the lakes close.

This species nests regularly on the lakes in the northern counties and especially about Green Bay.

Family ACCIPITRIDAE. Hawks and Eagles

40. *Astur atricapillus atricopillus* (Wilson). **Goshawk.** This freebooter from the north is an irregular winter visitor. Its presence is due presumably to the scarcity of grouse and rabbits within its natural range. An adult Goshawk[29] remained in the Lake Wingra woods from Jan. 1 to March 5, 1927. On one occasion it was flushed from the skeleton of a rabbit, but its main diet during the above period was Bob-white. The kills were invariably devoured on a stump or log. Another was seen Jan. 30, 1928 near Fitchburg. One was seen by Taylor[30] on Jan. 24, 1923.

41. *Accipiter velox* (Wilson). **Sharp-shinned Hawk.** This hawk is a migrant in small numbers. According to my notes, it is present in spring from April 8 to May 14 and in fall from September 5 to October 7. Betts saw one April 6, 1913.

42. *Accipiter cooperi* (Bonaparte). **Cooper's Hawk.** The Cooper's Hawk is a common summer resident and exceeds in number all other members of the family. The average date of arrival is April 5; the earliest March 28. It remains until October 24. This species winters rarely. One was seen December 19, 1920.

Nests with eggs have been found from May 1 to June 6. Mr. George French found eggs April 27, 1926. Most of the nests contain full sets of eggs by May 15.

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[29] Schorger, Auk 44 (1927) 271.
[30] Auk 43 (1926) 380.

43. *Buteo borealis borealis* (Gmelin). **Red-tailed Hawk.** Permanent resident. There is a well defined southward migration of northern birds in October. This species ranks third in number. Full sets of eggs have been found from April 10 to 22.

44. *Buteo borealis krideri* Hoopes. **Krider's Hawk.** This is a western form of the Red-tailed Hawk, presumably of regular occurrence in western Wisconsin in autumn.[31] Taylor[32] reports one seen in the spring of 1921 (Feb. 6). He has the following unpublished sight records: Jan. 23, 1923; and Oct. 14, 1925.

I am not aware of a specimen having been taken in the county. There are so great variations in the several races of Red-tails, *B. borealis borealis, B. borealis calurus,* and *B. borealis krideri,* all of which may occur in Wisconsin, that their identification is frequently difficult even with the skins in hand.

45. *Buteo lineatus lineatus* (Gmelin). **Red-shouldered Hawk.** Known only as an uncommon spring migrant at Madison from March 14 (Betts) to April 13. One was seen by Betts Jan. 11, 1914. This species is of regular occurence in the western part of the county and breeds in the Wisconsin River valley.

Mr. Alvin Cahn seems to have been more fortunate with this species for he states[33]: "Not an uncommon visitor——. A male collected had eaten two toads, a garter snake, and a number of May beetles."

46. *Buteo platypterus* (Vieillot). **Broad-winged Hawk.** Common migrant and fairly common summer resident. Arrives April 3 (Taylor) to May 1. The southward migration is completed for the most part by October 1. This is the least wary of all our hawks and it has been seen in well wooded, populous sections of Madison.

A set of three eggs was obtained May 27, 1922[34]. Mr. George French took a set of eggs May 24, and found a nest with young July 4, 1927.

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[31] Kumlien and Hollister, "Birds of Wisconsin" p. 63.

[32] Auk 39 (1922) 273.

[33] "An Ecological Survey of theWingra Springs Region, near Madison, Wisconsin." Bull. Wis. Nat. Hist. Soc. 13 (1915) 159.

[34] Schorger, Auk 39 (1922) 574.

47. *Triorchis lagopus sancti-johannis* (Gmelin). **Rough-legged Hawk.** This hawk appears in November and, unless driven south by heavy snows that render the procuring of food difficult, remains in diminished numbers throughout the winter. It is most common in spring during the last two weeks in March. It has been seen as late as April 20.

Kumlien and Hollister[35] record the finding of a nest in the eastern part of Dane County in May, 1872. The female had received a wound in the wing, that presumably prevented her from migrating.

48. *Aquila chrysaetos* (Linnaeus). **Golden Eagle.** Rare migrant. Information on this species is extremely meager. Captured eagles, reported as belonging to this species, have proved on examination to be immature Bald Eagles. Taylor reports one seen near Mazomanie October 26, 1928.

49. *Haliaeetus leucocephalus leucocephalus* (Linnaeus). **Bald Eagle.** The Bald Eagle is a fairly common visitor to the Madison region. Most of the records are for the winter months, just before the lakes freeze. I have seen it on the following occasions: September 10, 1922; December 12, 1925; December 11, 1927; and January 10, 1928. Betts saw one January 3, 1914. The following records are from Taylor's notes: October 14, 1921; September 14, 1922; May 6, 1923; May 2, 1924; February 11, 1927; and May 27, 1928. It is a not uncommon winter resident near Mazomanie where it is able to obtain from the Wisconsin River its usual diet of fish.

50. *Circus hudsonius* (Linnaeus). **Marsh Hawk.** . Common summer resident ranking second to the Cooper's Hawk in abundance. A few winter regularly unless the snow becomes too deep on the marshes. The average date of arrival in spring is March 16. There appears to be no well defined period to the fall migration, the decrease being gradual.

The Marsh Hawk is beneficial since it feeds largely on small rodents. I have, however, seen it in the act of striking down or devouring the following species of birds. Florida Gallinule (*Gallinula chloropus cachinnans*); Bobolink (*Dolichonyx oryzivorus*); Swamp Sparrow (*Melospiza*

[35] "Birds of Wisconsin," p. 64.

georgiana); and a chicken. The latter was from the University farm. From the band that it carried, it was found to be 58 days old.

A full set of eggs has been found by May 3. Mr. George French obtained a set of 5 eggs May 21, 1927. A second clutch of the same pair containing the exceptional number of 7 eggs was found June 12.

51. *Pandion haliaetus carolinensis* (Gmelin). **Osprey.** The Osprey is a fairly common migrant. It has been observed in spring from April 15 to May 24; and in fall from September 6 to 25.

52. *Falco peregrinus anatum* Bonaparte. **Duck Hawk.** This is one of our rarer hawks. The dates on which it has been noted are insufficiently early or late to cover the migrating period. It should arrive the middle of March and remain until November, if not a permanent resident.

The Duck Hawk nests preferably on cliffs and there are no suitable sites actually within the county. Three adjacent places are used with more or less regularity: Ferry Bluff, Sauk County, just across the river from Dane County; Devil's Lake, Sauk County; and Gibraltar Rock, Columbia County.

53. *Falco columbarius columbarius* Linnaeus. **Pigeon Hawk.** In my experience this is one of the rarest of the hawks, appearing regularly in the state. I saw one April 14, 1928, and this is the only occasion on which identification was positive. Taylor has seen it on the following occasions: May 7, 1923; May 22 and October 9,1924; and April 27, 1925.

54. *Falco sparverius sparverius* Linnaeus. **Sparrow Hawk.** This dainty falcon is a fairly common migrant, but an uncommon summer resident. A pair bred in the Wingra woods in 1914, and another pair on Picnic Point in 1928. In July the young birds are quite noisy and readily betray their presence. It is a rare winter resident, one being seen February 9, 1913.

The Sparrow Hawk sometimes appears during the latter half of March, but usually not until April. The average date of arrival is April 9; the earliest March 9, 1913. The fall migration begins in September and is completed by October 18.

Family TETRAONIDAE. Grouse

55. *Bonasa umbellus umbellus* (Linnaeus). **Ruffed Grouse.** Permanent resident, most numerous in the western half of the county. The actions of the Ruffed Grouse of the wilderness border on stupidity, but no cleverer bird exists than the grouse of civilized regions. In 1914 a brood was reared where the city reservoir now stands, near Sunset Point. This species is most widely distributed during winter. One or two birds usually winter in the Eagle Heights region, but disappear in late spring. A nest found at Cross Plains May 30, 1925 contained 11 eggs.

56. *Tympanuchus americanus americanus* (Reichenbach). **Prairie Chicken.** Permanent resident. There are indications of an influx of northern birds during the winter months when flocks containing 40 to 50 individuals are occasionally seen. The persistent draining of marshes renders it difficult for the species to maintain its ground. The large marsh at the north end of Lake Kegonsa is occupied permanently, and will probably remain so as it is unlikely to be changed by further drainage. While the various marshes seem equally attractive, on some the Prairie Chicken will not be found. No satisfactory explanation for this situation can be advanced.

A nest found in one of the Lake Wingra marshes on April 26, 1914, contained two eggs.

Family PERDICIDAE. Bob-whites, Quails

57. *Colinus virginianus virginianus* (Linnaeus). **Bob-white.** Common permanent resident. There has been no apparent change in the number of Bob-whites during the past fifteen years, though they have been protected by law. This situation is due largely to lack of suitable cover as a protection against natural enemies and the rigors of winter. While normally roosting upon the ground, I have found covies roosting in the dense foliage of spruce trees. Good indigenous cover is a thick stand of blackberry *(Rubus)*. During seasons of deep snow the best protection is afforded by the canopies formed by the wild grape overgrowing small trees and shrubs. In a winter of heavy snow the Bob-

white will remain in the vicinity of locust (*Robinia pseudacacia*) thickets and feed largely on the seeds. Many of the seed pods of this species remain on the tree until spring.

58. *Perdix perdix perdix* (Linnaeus). **Hungarian Partridge.** This species has been introduced from Europe where it is known as the Common or Grey Partridge. The name accepted in this country has its origin in the circumstance that the first birds were obtained from Hungarian dealers. The male is easily recognized by a horseshoe-shaped patch of chestnut on the lower breast. This partridge is partial to open and cultivated fields, and in other habits resembles the Bob-white. The first liberation of the species in Wisconsin was made in Waukesha County by Mr. Gustave Pabst, who on February 6, 1929 wrote as follows: "I started about nineteen years ago, both importing and buying stock birds from abroad and from dealers in this country. I have planted between five and six thousand birds, covering a territory of twelve to fifteen miles, replanting same every second year after the first planting and covering a total period of about six or eight years."

A flock of about twenty was seen ten miles east of Madison in May, 1927, by the late Professor George Kemmerer.

Family PHASIANIDAE. Pheasants

59. *Phasianus colchicus torquatus* (Gmelin). **Eastern Chinese Ring-necked Pheasant.** This bird was introduced very recently. Mr. William Aberg liberated 35 birds at Shorewood Hills in 1926. In April, 1927, the local chapter of the Izaak Walton League liberated near Lake Wingra 22 birds that had been trapped in South Dakota. In the fall of the same year, 160 birds were liberated in various parts of the county. The League was instrumental in having 600 birds hatched from eggs liberated in 1928.

Family RALLIDAE. Rails, Coots, and Gallinules

60. *Rallus elegans* Audubon. **King Rail.** Fairly common summer resident. The skill that so large a bird as the King Rail displays in hiding in sparse cover is astonishing.

The earliest spring arrival for Madison is April 21, 1911[36] (by Roland E. Kremers). Betts observed it at Madison April 23, 1916. It has been found at Delavan as late as October 22, 1894, but in the Madison region not after September 24.

61. *Rallus virginiana* Linnaeus. **Virginia Rail.** This miniature of the King Rail is a common summer resident, arriving the first week in May and becoming common by the 10th. The earliest arrival[37] is April 28 (Taylor). The latest fall record is the capture of an exhausted bird at Madison on the night of October 21, 1913, during a premature snow storm. A very interesting description of the food habits of the captive has been given by Cahn[38].

Sets of eggs have been found from May 30 to June 5. The nest is usually placed in a tuft of marsh grass on a hillock.

62. *Porzana carolina* (Linnaeus). **Sora.** The jaunty Sora is an abundant summer resident arriving usually the last week in April. It is sometimes common by the middle of the month as 10 were seen April 17, 1916. The earliest date is April 10 (Taylor). The latest fall record is October 23, 1921. The Sora is a hardy bird. Of two seen in a frozen marsh on December 28, 1913, one was caught and found to be minus the right wing.[39] At the report of a gun, it has the disconcerting habit of dropping to the ground whether hit or not.

George French found two nests on May 30 containing 9 and 11 eggs respectively.

63. *Coturnicops noveboracensis* (Gmelin). **Yellow Rail.** A specimen was taken May 2, 1920 by Mr. Warner Taylor and this is the only known capture for the county. Bent[40] gives a record for Madison for May 13, 1911. The Yellow Rail is so secretive and difficult to flush that it is probably much more common than the records indicate. It has been found in Wisconsin from April 23 to October 13.

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[36] Bent, U. S. Nat. Mus. Bull. 135 (1926) 266.

[37] Bent, *vide supra*, p. 300, gives April 19, 1917. This is an error and applies to the Sora.

[38] Auk 32 (1915) 91.

[39] Schorger, Auk 31 (1914) 256.

[40] U. S. Nat. Mus. Bull. 135 (1926) 325; record taken from Wisconsin Arbor and Bird Day Annual for 1912.

64. *Gallinula chloropus cachinnans* Bangs. **Florida Gallinule.** Summer resident, arriving the end of April, and becoming common by May 10. The earliest record is April 16, 1927. It has not been noted in fall after October 8.

Nests with apparently full sets of eggs have been found from May 30 to June 13. A nest found by G. French on May 30 contained 13 eggs. Deposition of eggs begins the middle of May. The young hatch irregularly and leave the nest soon afterwards, at least on the slightest disturbance, as I have found only young recently hatched. Very small young have been noted as late as August 11.

65. *Fulica americana* Gmelin. **Coot.** The "Mud-hen" is a common summer resident. The wintering birds are mostly crippled. It arrives usually the last week in March, and is common to abundant by April 8. In 1922 it arrived March 12 and was common on the 26th. In fall the Coots begin to mass by Sept. 20, and rafts of one to five thousand birds are not uncommon in October. It remains in numbers, especially on Lake Mendota, until the ice forms. One hundred were seen December 16, 1928.

Nests with eggs have been found from June 4 to 13.

Shore Birds

The county in general is not attractive to shore birds. They prefer mud flats as feeding grounds. The beaches that exist on the lake shores consist largely of sand; as a result the shore birds are found mainly about the muddy margins of flooded marshes and small ponds. The Wilson's Snipe prefers marsh land with standing water and with vegetation sufficiently short that the view is unobstructed. There remain still areas of grazed marsh land that attract this species in large numbers.

There have been two occasions on which shore birds have been present in unusual numbers. In May 1915 a dredge working above the Widespread created a level area of several acres of black mud and marl. Indian Lake near Springfield Corners was drained the summer of 1927. On July 17, on an area of about 20 acres of mud, there were 500 shore birds consisting mainly of Lesser Yellowlegs, Solitary Sandpipers, Semipalmated Sandpipers, Least

Sandpipers, and Pectoral Sandpipers. Previous to being drained this lake drew very few birds, so that it was not a customary stop during migration. It is apparent that those that chanced to pass within sight of the lake bottom recognized it as a rich feeding ground and stopped accordingly. It is doubtful if birds beyond an air path two miles wide were drawn down. If the same attractions had existed elsewhere, a line running east and west through the county would have contained over 10,000 shore birds.

Family CHARADRIIDAE. Plovers and Turnstones

66. *Charadrius semipalmatus* (Bonaparte). **Semipalmated Plover.** Common migrant. The average date of arrival is May 9, and it becomes common by May 15. The earliest date is May 3, 1914 (Betts). It has not been noted after May 31.

This plover is less common in fall than in spring. The extreme dates are July 30, 1922 and September 19, 1926. Most of the birds pass south the last week in August.

67. *Oxyechus vociferus vociferus* (Linnaeus). **Killdeer.** This noisy shore bird is an abundant summer resident, and is the first of the family to arrive from the south. The average date of arrival is March 17; the earliest March 5, 1921. Large flocks numbering as high as 150 birds are to be found in September. They disappear gradually, the average date of departure being October 25. Frequently they do not depart until November, the latest date being Nov. 10, 1923.

The eggs are usually deposited in May, but occasionally they must be laid the latter part of April since tiny young have been found by May 9. They have also been found as late as July 18. The late dates undoubtedly represent a second attempt as a result of the destruction of the first nest. This species relies on concealing coloration and not natural cover to protect the nest. The latter is usually placed in a pasture, a recently ploughed field, or one about to be ploughed. As a result the first set of eggs is frequently destroyed.

68. *Squatarola squatarola* (Linnaeus). **Black-bellied Plover.** This plover is now an uncommon migrant. It

was formerly abundant in migration on the virgin prairies of the state. Mr. H. L. Skavlem informed me that this species and the Golden Plover were very tame and followed the plow like chickens, especially when prairie land was being broken. Among hunters it had the euphonius name of "Bull-neck".

There are no more than a score of records for the Black-bellied Plover during the past 15 years. Nearly all of these fall between May 20 and 30. The earliest date of arrival is May 17, 1914 (Betts). There is but one fall record. This bird, seen near De Forest on September 18, 1921, had the black breast and belly characteristic of the full breeding plumage.

69. *Arenaria interpres morinella* (Linnaeus). **Ruddy Turnstone.** The bizarrely colored Turnstone is an uncommon spring migrant but cannot be called rare. It has been found from May 19 (Betts) to May 27. Mr. John Gundlach found 13 on the bar in University Bay May 27, 1925. There are no fall records.

Family SCOLOPACIDAE. Woodcocks, Snipes, Sandpipers, etc.

70. *Philohela minor* (Gmelin). **Woodcock.** Summer resident. The Woodcock is an early migrant, reaching us the latter part of March. The sight of this bird standing in snow so deep that it can scarcely walk is incongruous. The extreme dates are March 18, 1918 to October 21, 1921. This species is most numerous in the western part of the county, particularly along the Wisconsin River. It is seldom, however, that more than two or three birds are flushed in a day. Removal from the list of game birds is advisable.

The Woodcock nests frequently in the Wingra woods. Here French found one with young May 22, 1926. Taylor found a nest with 2 eggs near Mazomanie, May 24, 1925.

On June 5, 1927 I found a nest with 2 eggs at Cross Plains. It was situated in the edge of a woods on a high hill and within five feet of a well used cow-path.

71. *Capella delicata* (Ord). **Wilson's Snipe.** This fine game bird is an abundant migrant. It is not uncommon

as a winter resident about certain spring holes. Though formerly a common summer resident, there is no satisfactory breeding record within recent years. It frequently arrives the end of March, the earliest date being March 19, 1927; average date of arrival April 6. Nearly all have departed by the end of April, but individuals are frequently found up to May 16. The average date of fall arrival is Aug. 2; the earliest July 24, 1920. The birds do not become common until the last week in September. From this it might be concluded that the earliest birds are local, were it not that during the period of two months covering the nesting season no snipe have been noted. The height of the migration is reached in October when as many as 200 birds have been seen in one day. A gradual decrease in numbers has taken place during the past 15 years. Stragglers remain until the marshes freeze. The latest date is Nov. 25, 1920.

The stomachs of birds taken in Dane County in autumn were forwarded to the Biological Survey for examination. The principal food is the white larva of a fly of the family Dolichopodidae. Frequently a large portion of the food consists of seeds of: sedge (Carex; Cyperus); bur-reed (Sparganium); mare's tail (*Hippuris vulgaris*); buck bean (*Menyanthes trifoliata*); and crowfoot (Ranunculus). On Oct. 31, 1925, I shot a Wilson's Snipe along the shore of Lake Mendota. As soon as the bird drifted in it was placed on a sheet of paper, whereupon leeches (*Dina parva*) began crawling from its mouth. In all 39 entire leeches, ranging from three-fourths to one inch in length, were accounted for subsequently. The size and nature of the meal is surprising.

72. *Numenius hudsonicus* Latham. **Hudsonian Curlew.** Rare migrant. Taylor saw one May 24, 1926. Early in the morning of October 1, 1928, Mr. John Gundlach saw three curlews alight on a mud bar in the Widespread. The birds left before he could approach near enough for a shot. They were very probably of this species. The Eskimo Curlew is practically extinct. The Long-billed Curlew was never common in Wisconsin and disappeared even from Minnesota twenty-five years ago.

73. *Bartramia longicauda* (Bechstein). **Upland Plover.** This species is a summer resident in very small numbers.[41] There are seasons when none have been observed. The average date of arrival for southern Wisconsin is April 18.[42] Taylor observed it April 11. The latest fall record is Aug. 8, 1926.

74. *Actitis macularia* (Linnaeus). **Spotted Sandpiper.** Common summer resident. The average date of arrival is April 29; the earliest April 20, 1914 (Betts). The fall migration is usually completed by September 20. The latest date is October 10, 1926.

75. *Tringa solitaria solitaria* (Wilson). **Solitary Sandpiper.** This sandpiper is a common migrant, the average date of arrival in spring being May 2; the earliest April 25 (Taylor). The average date of departure for the north is May 18; the latest May 27, 1917. Its sojourn in the north is short. It was seen by Betts July 4, 1913, and by the writer July 7, 1929. The average date of arrival is July 18. The migration is completed on the average by September 30, the latest date being October 8, 1926.

76. *Catoptrophorus semipalmatus inornatus* (Brewster). **Western Willet.** Very rare migrant. There is but one record, that of a bird found on the bar in University Bay by Mr. John Gundlach, July 2, 1925. Taylor[43] attempted its collection.

77. *Totanus melanoleucus* (Gmelin). **Greater Yellowlegs.** A regular migrant in small numbers. It is much less numerous than *T. flavipes*. The proportion one of the former to seventy-five of the latter is not far wrong. The average date of arrival is April 20; the earliest April 3, 1921. In 1914 it was observed as late as May 17 by Betts. The early date (by Roland E. Kremers) of July 29 for arrival at Madison in fall is given by Bent.[44] Nearly all the records fall between Sept. 25 and Oct. 11. It is exceptional to find a flock at any season numbering more than 6 to 8

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[41] Taylor, Auk. 39 (1922) 273; 40 (1923) 339; 43 (1926) 251; Schorger, *Ibid.* 44 (1927) 235.
[42] Cooke, Biological Survey, Bull. 35 (Revised), (1912), p. 66.
[43] Auk 43 (1926) 251.
[44] U. S. Nat. Mus. Bull. 142 (1927) 335.

birds. One was shot out of a flock of 8 Oct. 11, 1919, the latest date on which it has been found.

78. *Totanus flavipes* (Gmelin). **Lesser Yellow-legs.** Abundant migrant arriving on the average April 27. The earliest date is April 2, 1916 (Betts). Ordinarily it is not common before May 5, though 38 were seen April 14, 1928. The average date of departure is May 22; the latest May 30, 1928.

Scarcely six weeks elapse before the note of the Lesser Yellow-legs is heard again. The average date of arrival is July 19, the earliest July 7, 1929. It is common from July 30 to Sept. 24. The average date of departure is Sept. 28; the latest Oct. 15, 1927.

79. *Pisobia maculata* (Vieillot). **Pectoral Sandpiper.** This sandpiper is a common migrant. It is found frequently in cultivated fields and meadows as well as near the water. On May 3, 1925, a flock of 200 was found in a partially ploughed clover field near Lake Kegonsa. The spring arrivals are erratic, dating from the last of March to the first of May. The earliest date is March 25, 1928. On March 31, 1917 a flock of 20 was found on ice cakes in University Bay. The average date of departure is May 19; the latest May 26, 1928.

The average date of arrival in fall is July 23; the earliest July 9, 1927. The average date of departure is Oct. 12; the latest Oct. 18, 1916.

80. *Pisobia fuscicollis* (Vieillot). **White-rumped Sandpiper.** The "White-rump" is one of the rarer shore birds. Taylor[45] states: "On May 21, 1923, I collected one specimen; on May 28, 1924, under favorable conditions I identified six; on May 3, 1925, two; on May 30, I collected one, and on June 5, three among a flock of a dozen or so."

I have found it on the following occasions: one was taken May 10,[46] and another seen May 20, 1914; two seen May 22, 1915; three seen May 20, 1928; and one seen Aug. 12 and 14, 1926. Betts had the following records: May 9, 17, and 20, 1914; and May 22, 1915.

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[45] Auk 43 (1926) 250.
[46] Auk 43 (1926) 556.

81. *Pisobia bairdi* (Coues). **Baird's Sandpiper.** This sandpiper also is not common. It occurs much more frequently in fall than in spring. The only spring record is one taken by Taylor[47] June 5, 1925 from a flock of White-rumped Sandpipers.

This species was found on nine occasions during the fall of 1926 and 1928, between Aug. 8 and Sept. 15. All but one of the records were for August. In 1926, I took a lone female Aug. 15, and another female from a flock of four Aug. 27.[48]

82. *Pisobia minutilla* (Vieillot). **Least Sandpiper.** Common migrant whose average date of arrival is May 13. The earliest date is May 3 (Taylor). It is most numerous May 15 to 20. The latest date of departure is May 27, 1928.

The average date of the return is July 16. The earliest date is July 5, 1913 (Betts). The migration is usually completed by Sept. 15, the latest date being Oct. 7, 1928.

83. *Pelidna alpina sakhalina* (Vieillot). **Red-backed Sandpiper.** This shore bird is common in spring, but rare in autumn. Most of the birds appear to return from the Hudson Bay breeding grounds by way of the Atlantic coast. The average date of arrival in spring is May 13; the earliest May 9, 1926. The height of the migration is May 17 to 22. A flock of 75 birds was seen May 22, 1915. The latest date of departure is May 31, 1914.

The fall records are scanty. The following dates are given by Betts: Nov. 1, 1914; and Nov. 15, 1915. I have found it on only one occasion, Nov. 13, 1927, when two were collected at Lake Kegonsa.

84. *Limnodromus griseus scolopaceus* (Say). **Long-billed Dowitcher.** A specimen was referred to this form by Dr. A. Wetmore. It is unlikely that the eastern bird (*L. griseus griseus*) will be found. Formerly an abundant migrant, now uncommon. The extreme dates of its occurrence in spring are May 6, 1928, and May 22, 1915. The average date of arrival is May 15. I have never found more than 4 birds in one flock except on May 17, 1925 when

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[47] Auk 43 (1926) 251.
[48] Auk 44 (1927) 262.

26 were seen.[49] The only fall record is a male taken Aug. 12, 1926.[50]

85. *Micropalama himantopus* (Bonaparte). **Stilt Sandpiper.** The Stilt Sandpiper is a rare migrant. John Main took one May 18, 1927, and this is the only spring record.

In the summer of 1926, I found this species on several occasions as follows:[51] 8 were seen and 3 taken Aug. 7; 2 were seen and one taken Aug. 8; 2 were seen and one taken Aug. 14; and a lone bird was taken Aug. 25. John Main took one Sept. 12. All of the above records were obtained on the same pond.

86. *Ereunetes pusillus* (Linnaeus). **Semipalmated Sandpiper.** Common migrant. The average date of arrival is May 15; the earliest May 3 (Taylor). It is found in largest numbers from May 28 to 31. Strangely, it has not been noted after the latter date.

The extreme dates for the return migration are July 16, 1927 and Sept. 15, 1928. The height of the movement is Aug. 14 to 28.

87. *Limosa fedoa* (Linnaeus). **Marbled Godwit.** The Marbled Godwit was never common in Wisconsin and is now merely a straggler from its principal range, which is west of the Mississippi. Taylor[52] has reported one seen on May 18, 1922.

88. *Crocethia leuchophaea* (Pallas). **Sanderling.** The Sanderling is an uncommon migrant. The data are too few to furnish reliable limits to the migration periods. It has been found in spring from May 11 (Taylor) to May 23 (Betts). My fall records extend from Aug. 26 to Sept. 15. The latest record is Nov. 5, 1926, when Mr. John Gundlach collected a Sanderling on Picnic Point, Lake Mendota.

The statement of Kumlien and Hollister[53] that this species "frequents the sandy shores exclusively" cannot be confirmed. I have seen it feeding on mud flats with other shore birds, both at Lake Koshkonong and in the Madison region.

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[49] Auk 43 (1926) 557.
[50] Auk 44 (1927) 261.
[51] Auk 44 (1927) 261.
[52] Auk 40 (1923) 339.
[53] Bull. Wis. Nat. Hist. Soc. 3 (1903) 48.

Family, PHALAROPODIDAE. Phalaropes

89. *Steganopus tricolor* Vieillot. **Wilson's Phalarope.** The exquisite Wilson's Phalarope is found in small numbers during the migration period and probably breeds within the county. Mr. Louis Sumner collected a set of eggs June 5, 1887 in the marsh at the fair grounds at Madison. Taylor[54] saw two June 19, 1925 at Mud Lake (Jefferson Co.).

The earliest date of arrival is May 3 (Taylor). This species leaves its breeding grounds early, the southward movement being completed usually in August. It has been taken on the extreme dates July 12 and Aug. 13.

The spinning motion which the Phalaropes undergo while sitting on the water, is reputed to result in bringing to the surface minute forms of animal life upon which the birds feed. I watched a pair of Wilson's Phalaropes May 14, 1928, feeding upon small insects hovering thickly over the water. The birds went through precisely the same spinning motion in capturing the insects from the air. They were merely observing a simple mechanical principle. By pivoting, food can be seized most rapidly over a large area with a minimum of effort.

90. *Lobipes lobatus* (Linnaeus). **Northern Phalarope.** Rare migrant. Warner Taylor reports one seen May 20, 1917. I collected one Sept. 3, 1923 in a marsh near Madison, and another Sept. 24, 1927 at a pond near Springfield Corners.[55] The date Oct. 14, 1927 given in the latter reference is an error.

Family LARIDAE. Gulls and Terns

91. *Larus argentatus* Pontoppidan. **Herring Gull.** This species, though present throughout most of the year, does not breed. It frequently winters where the Yahara River remains open, and immature and non-breeding birds are common throughout the summer. This gull arrives early in March, the average date being the 13th. It is numerous until the middle of April, occasionally until the middle of May.

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[54] Auk 43 (1926) 250.
[55] Auk 43 (1926) 556; 45 (1928) 106.

In fall it remains for the most part on the lakes, but in spring hundreds may be found in cultivated fields and around temporary pools. It is less common in fall than in spring, arriving on the average Oct. 7 and remaining until the lakes close.

92. *Larus delawarensis* Ord. **Ring-billed Gull.** Common migrant, but less numerous than the preceding species with which it associates. The average date of arrival is March 30; the earliest March 15, 1913 (Betts). It usually departs by May 20, but on May 29, 1927, a mixed flock of immature birds consisting of 15 Herring Gulls and 35 Ring-billed Gulls was seen in a meadow near Lake Wingra. It is occasionally found in July and August. It appears in fall the middle of October, the earliest date being September 20, 1914.

93. *Larus pipixcan* Wagler. **Franklin's Gull.** Kumlien and Hollister[56] state that in May, 1870 considerable numbers of this species were seen following the plow near Rockdale, Dane County. There is only one subsequent record. Fragments of a bird of this species were found April 23, 1911, on the shore of Lake Mendota. The wing by which the species was identified at Washington is preserved in the Biological Department of the University.[57]

94. *Larus philadelphia* (Ord). **Bonaparte's Gull.** This gull is a fairly common spring migrant. The average date of arrival is April 26; the earliest April 9, 1916 (Betts.) It has not been noted after May 20. The fall migration takes a southeasterly direction over the Great Lakes, and records for the interior are scarce. I saw an immature Bonaparte's Gull at Lake Koshkonong August 26, 1928, but this bird may have spent the summer there.

95. *Sterna hirundo* Linnaeus. **Common Tern.** The information on the status of this species and Forster's Tern *(S. forsteri)* is very unsatisfactory. Identification by the eye is unreliable. Each species has characteristic notes, but too frequently they cannot be heard. *S. hirundo* utters a harsh "tee-ar-r-r", and *S. forsteri* a hoarse "zru-r-up." The Common Tern is the more abundant bird, but the mi-

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[56] Bull. Wis. Nat. Hist. Soc. 3 (1903) 10.
[57] Conover, Auk 29 (1912) 388.

gration dates given below cannot be referred to this species alone with certainty.

The Common Tern arrives on the average May 5, the earliest date being April 22, 1928. It is common the last two weeks in May, and remains until June 15. Individuals are occasionally seen in summer. It has been observed in fall from September 10 to October 14, but it is far less common at this season than in spring.

96. *Sterna forsteri* Nuttall. **Forster's Tern.** There is only one record backed by a specimen. Mr. Warner Taylor took one May 14, 1923.[58] Based on identification by note, Forster's Tern occurs mainly between May 17 and 27.

97. *Sterna caspia* Pallas. **Caspian Tern.** This large tern is a fairly common migrant. There are the following spring records: one seen May 8, 1913 (Betts); two seen May 17,1922[59]; one May 18, 1919; and two May 27, 1924 (Taylor).

The fall records are as follows: two seen September 18, 1915 (Schorger); seven seen September 12, 1925 (John Gundlach); small flocks September 16, 1926 and September 10, 1927; and one bird August 30, 1928 (Harry Anderson); two seen September 16, 1923 (Taylor).

98. *Chlidonias nigra surinamensis* (Gmelin). **Black Tern.** Abundant summer resident. The average date of arrival is May 6; the earliest April 24 (Taylor). The average date of departure in fall is September 12; the latest September 20, 1914.

Nests with full sets of eggs have been found from May 30 to June 19.

Family COLUMBIDAE. Pigeons and Doves

99. *Zenaidura macroura carolinensis* (Linnaeus). **Mourning Dove.** Common summer resident, occasionally wintering. The average date of arrival is April 2; the earliest March 20, 1927. The average date of departure is October 13.

The breeding season is extraordinarily long. I have found nests with eggs from April 18 to September 12.

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[58] Auk 43 (1926) 250.
[59] Taylor, Auk 40 (1923) 339.

Family CUCULIDAE. Cuckoos

100. *Coccyzus americanus americanus* (Linnaeus). **Yellow-billed Cuckoo.** This species is a fairly common summer resident that is heard more often than seen. As a rule it is one of the latest of the migratory birds to arrive. It is irregular in its movements, arriving one year the middle of May, and in another not until the first week in June. The earliest date of arrival is May 12 (Taylor). The average date of arrival is about May 26. The average date of departure in autumn is September 19; the latest September 27, 1914 (Betts).

Nests with eggs have been found from June 5 to Aug. 5, the majority the second week in June.

101. *Coccyzus erythrophthalmus* (Wilson). **Black-billed Cuckoo.** This species is more numerous than the preceding and arrives earlier, the average date being May 18. The earliest date is May 10, 1927. The average date of departure is September 20; the latest September 26, 1926.

Nests with eggs have been found from May 31 to June 6.

Family TYTONIDAE. Barn Owls

102. *Tyto alba pratincola* (Bonaparte). **Barn Owl.** Uncommon permanent resident. One was seen August 25, 1917. On October 1, 1924, five fully grown young were taken from a gable at the State Hospital on Lake Mendota[60]. These were placed in the zoological collection at Vilas Park and at the present date four are living. Warner Taylor saw one near Oregon April 3, 1920.

Family STRIGIDAE. Horned Owls, etc.

103. *Otus asio asio* (Linnaeus). **Screech Owl.** Common permanent resident. Eggs have been found April 11 (French) and young able to fly have been seen by June 11.

104. *Bubo virginianus virginianus* (Gmelin). **Great Horned Owl.** Common permanent resident. Eggs have been found from February 11 to March 16.

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[60] Schorger, Auk 42 (1925) 131.

105. *Nyctea nyctea* (Linnaeus). **Snowy Owl.** Occasional winter visitor. One killed near Morrisonville was brought to Madison to be mounted Nov. 30, 1921. In February, 1922, a Snowy Owl spent ten days on the farm of George Williamson on Lake Waubesa [61].

106. *Strix varia varia* Barton. **Barred Owl.** Permanent resident, more common in the woods of the Wisconsin River bottoms than elsewhere.

107. *Asio wilsonianus* (Lesson). **Long-eared Owl.** This owl is a fairly common permanent resident. It uses the same roost continuously, if undisturbed, this being located in conifers when available.

On May 5, 1917 three eggs and two callow young were found in an old crow's nest. The sitting bird when flushed uttered a "meuw" that brought its mate instantly. The parents would drop to the ground and flutter along as though crippled.

108. *Asio flammeus* (Pontoppidian). **Short-eared Owl.** Permanent resident. During the winter months concentration of local birds or migrants frequently takes place in a marsh where field mice are numerous. On March 8, 1913 eleven were flushed from the marsh at the west end of Lake Wingra. When the marshes are buried in snow, this owl commonly spends the day in those oak trees near the marshes that retain a large portion of their leaves.

109. *Cryptoglaux acadica acadica* (Gmelin). **Saw-whet** Owl. This tiny owl is a rare migrant. It may be resident throughout the year, but there are no summer or breeding records. One was captured at Madison, October 15, 1915 by Professor E. R. Maurer. The skin, No. 1169, was preserved by Prof. George Wagner and is now in the University collection. Mr. Warner Taylor on April 22, 1926 found a wing and foot of this species in the Wingra woods. I took a male near College Hills, November 19, 1927.[61a]

Family CAPRIMULGIDAE. Whip-poor-wills, Nighthawks

110. *Antrostomus vociferus vociferus* (Wilson). **Whip-poor-will.** Rather common summer resident, especially in

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[61] Schorger, Auk 39 (1922) 574.
[61a] Auk 46 (1929) 250.

the western portion of the county. The average date of arrival is May 10; the earliest date April 21, 1923. The average date of departure in fall is September 21; the latest date October 1, 1918. The Whip-poor-will is vocal throughout the entire period of its presence.

A nest with one egg was found June 18. Another nest contained a half-grown young June 17.

111. *Chordeiles minor minor* (Forster). **Nighthawk.** Common summer resident migrating in large flocks. The average date of arrival is May 14; the earliest date May 6, 1913 (Betts). The fall migration begins in August and is completed on the average by September 10. The latest date of departure is September 25, 1915.

A nest with 2 eggs was found June 12. The young are able to fly by July 17.

Family MICROPODIDAE. Swifts

112. *Chaetura pelagica* (Linnaeus). **Chimney Swift.** Common summer resident, arriving on the average April 24. The earliest date is April 9, 1917. The birds are numerous on the date of arrival or shortly thereafter. The final date of departure varies greatly. Some years none are seen after the middle of September, in others they may be found through the third week in October. The average date of departure is October 6, the latest date being November 4, 1922.

I have seen a nest built on the interior side of a barn.

Family TROCHILIDAE. Hummingbirds

113. *Archilochus colubris* (Linnaeus). **Ruby-throated Hummingbird.** The Ruby-throat is a common summer resident. The average date of arrival is May 17, the earliest date May 10, 1914. The average date of departure in the fall is September 18; the latest date September 23, 1916.

Eggs have been found from July 13 to August 5.

Family ALCEDINIDAE. Kingfishers

114. *Ceryle alcyon* (Linnaeus). **Belted Kingfisher.** The familiar rattle of the Kingfisher is to be heard the end

of March or the first of April. The average date of arrival is March 31; the earliest date March 16, 1919. The average date of departure is October 27. It is occasionally found near creeks long after the lakes are closed. The latest date is December 20, 1925.

Family PICIDAE. Woodpeckers

115. *Colaptes auratus luteus* Bangs. **Northern Flicker.** Common summer resident, occasionally wintering. The Flicker appears the end of March or the first of April, the average date being March 28. The earliest date is March 16, 1919. The arriving Flicker invariably calls while the wintering birds are usually silent. The average date of departure is October 19. November and December birds may be final departures or winter residents.

Nests with eggs have been found from May 10 to 30.

116. *Ceophloeus pileatus abieticola* (Bangs). **Northern Pileated Woodpecker.** This magnificant woodpecker is a permanent resident in the woods near the Wisconsin River[62].

117. *Centurus carolinus* (Linnaeus). **Red-bellied Woodpecker.** Fairly common permanent resident near the Wisconsin River. During the winter the range is extended. It is rare in the Madison region during the summer, but not uncommon at other seasons.

118. *Melanerpes erythrocephalus* (Linnaeus). **Red-headed Woodpecker.** Permanent resident whose numbers are greatly reduced in winter. There appears to be no relation between the abundance of mast and the number of wintering birds. The migrants appear from April 25 to May 2, and the majority have departed by the first week in September. Approximately as many birds of this species are killed by automobiles as of all others combined.

Nests with eggs are found usually from May 30 to June 5.

119. *Sphyrapicus varius varius* (Linnaeus). **Yellow-bellied Sapsucker.** Common migrant, wintering rarely. One was collected Dec. 25, 1926[63]. The average date of

[62] Taylor, Auk 39 (1922) 273; Schorger, Ibid. 44 (1927) 236.
[63] Schorger, Auk 44 (1927) 262.

arrival is April 4; the earliest March 20, 1920. The migration is at its height April 15, and is completed largely by May 1, though stragglers have been noted as late as May 19. The main movement in autumn takes place the last week in September and the first week in October. The extreme dates of arrival and departure are September 15, 1918 and October 25, 1920.

120. *Dryobates villosus villosus* (Linnaeus). *Hairy* **Woodpecker.** Common permanent resident. The opening to the nest of this species is usually drilled through a shell of live wood to reach a decayed interior. A nest found May 13 contained 3 eggs.

121. *Dryobates pubescens medianus* (Swainson). **Downy Woodpecker.** Common permanent resident.

Nests with eggs have been found from May 13 to June 5.

(To be concluded).

RAINFALL MAPS OF WISCONSIN AND ADJOINING STATES

ERIC R. MILLER

The maps accompanying this paper are based on a new computation of the average rainfall. Earlier maps and discussions of the rainfall of Wisconsin are listed at the end.

The data are derived from observations made by and under the supervision of the U. S. Weather Bureau, and with standard rain gages. The observing stations are of two classes, (1) regular stations, manned by paid observers, and equipped with automatic recording gages, (2) cooperative stations, operated by public spirited citizens who perform the duty voluntarily, equipped with non-registering gages. The relative number and density of stations from which data were used are given in the following table:

	Observing stations	Reg.	Co-op.	Sq. mi. per station
Illinois (Northern)	19	1	18	945
Iowa	51	7#	44	1090
Michigan (Upper Peninsula)	20	4	16	818
Minnesota (south of Lat. 47½)	33	3	30	1745
Wisconsin	81	5	76	708
Total stations	204	20	184	984

Including Omaha, Neb.

The period of 31 years from 1897 to 1927 inclusive was taken as standard, and the records for only those years were used for stations with longer records. Missing observations within that period were estimated, and shorter periods of observation at 46 places in Wisconsin, and 16 in upper Michigan were extrapolated by comparison with surrounding observation points.

No corrections have been applied, beyond the extrapolation just mentioned, and the elimination of typographical errors.

It is well-known that the gaging of rain is not independent of wind, the catch diminishing the stronger the wind. The diminution is still greater in the case of snow. The regular stations of the Weather Bureau are generally located on high buildings in cities, and in plotting these charts it was found that their catch in the warmer months was less than at cooperative stations, which usually have a ground exposure. In winter the professional observer adjusts record of snow to correspond with the accretion of fresh snow on the ground, while the cooperative observer continues gage measurements. The cooperative observers are found in general to have less winter precipitation than the regular observers. As an example, the regular station at Duluth has a 31-year average precipitation for January of 1.01 inches, while the cooperative observer in the contiguous city of Superior, has only 0.58 inches adjusted average, based on 19 years of observations. On the other hand, the Duluth average for the 6 months, April-September, is 18.70 inches, against 19.76 for Superior.

Although precipitation is neither increasing nor decreasing permanently, its yearly deviations from the average are highly erratic. It is for this reason that care was taken to average the same period of years at all stations. Beyond this, the variations are local, especially in the warmer months, whence it is easily conceivable that some of the features of these maps are accidental. It is intended to study the dispersion of the data employed in these maps at some later time, but in the meantime it is of interest to remark that previous studies have shown that the average deviation of the annual rainfalls rises from 10% of the average in the Upper Peninsula of Michigan to 20% in southwestern Iowa.

That the main features of the distribution of rainfall shown by these maps are persistent can be verified by comparison with figures 2 and 8 of Kincer, (4).

Most of the precipitation in Wisconsin and adjacent states falls in connection with cyclonic storms. These move from west to east, but on account of their centripetal circulation and the western mountain barrier, their supply of moisture comes from the Gulf of Mexico and the Atlantic ocean. Decrease of rainfall with distance from source is plainly seen on these maps, especially from Illinois and southern Iowa to northwestern Minnesota. The importance of the Great Lakes depends upon the season. In winter these lakes remain open, so that they are relatively much warmer than the land. Their vapor is then the source of heavy snowfalls on lee shores, e. g. the northern shore of the Upper Peninsula in map 3. A reach of wind across more than 30 miles of water appears to be essential, as the heavy snowfalls do not appear along the western end of Lake Superior, until the prevailing northwest winds have passed Bayfield Peninsula. In summer the heavy rains occur mostly in summer thunderstorms, which must be regarded as local convectional overturnings, although they mostly occur during the passage of large cyclonic whirls. In summer, however, the Great Lakes are relatively cool, conditions adverse to local convection. Map 2 shows that the summer rainfall is deficient around the lake shores.

The rising of air is considered by meteorologists to be the cause of rainfall. This is paradoxical to the lay mind which has become attached to the erroneous explanation that the rain is due to contact with the cold upper atmosphere. The correct explanation is that rising air expands to equalize its internal pressure with the external pressure, which diminishes with height. This expansion does work at the expense of the temperature. Consequently the cooling goes on continuously at a rate proportional to the rate of rising. We expect to find heavier rainfall where the ascent is fastest. Ascent in cyclonic whirls and thunderstorms is not localized, but highlands cause localized ascents of air, and it is this factor that explains the heavier rainfall in western and northern Wisconsin, and the smaller rainfall of the level lands extending from Green Bay up the Fox River valley, down the lower Wisconsin valley, and up and down the Mississippi valley. Additional discussion of the rainfall distribution of this region will be found in the papers listed below, of which Kincer must be mentioned as containing an extensive bibliography.

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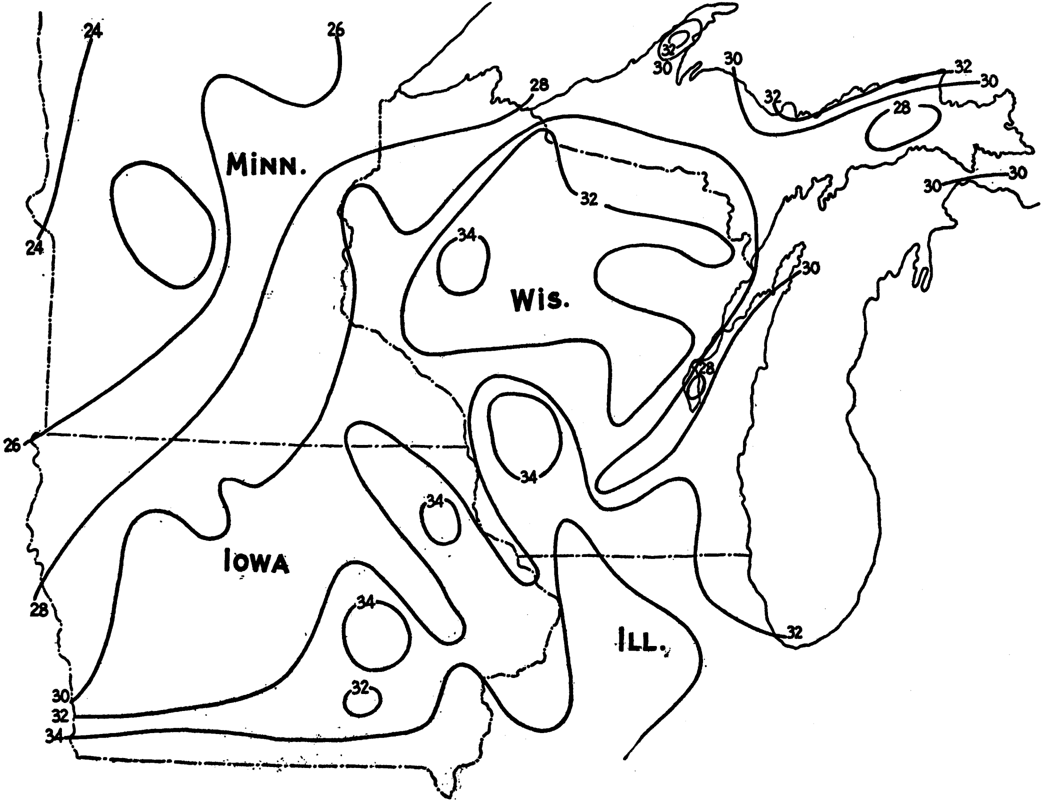
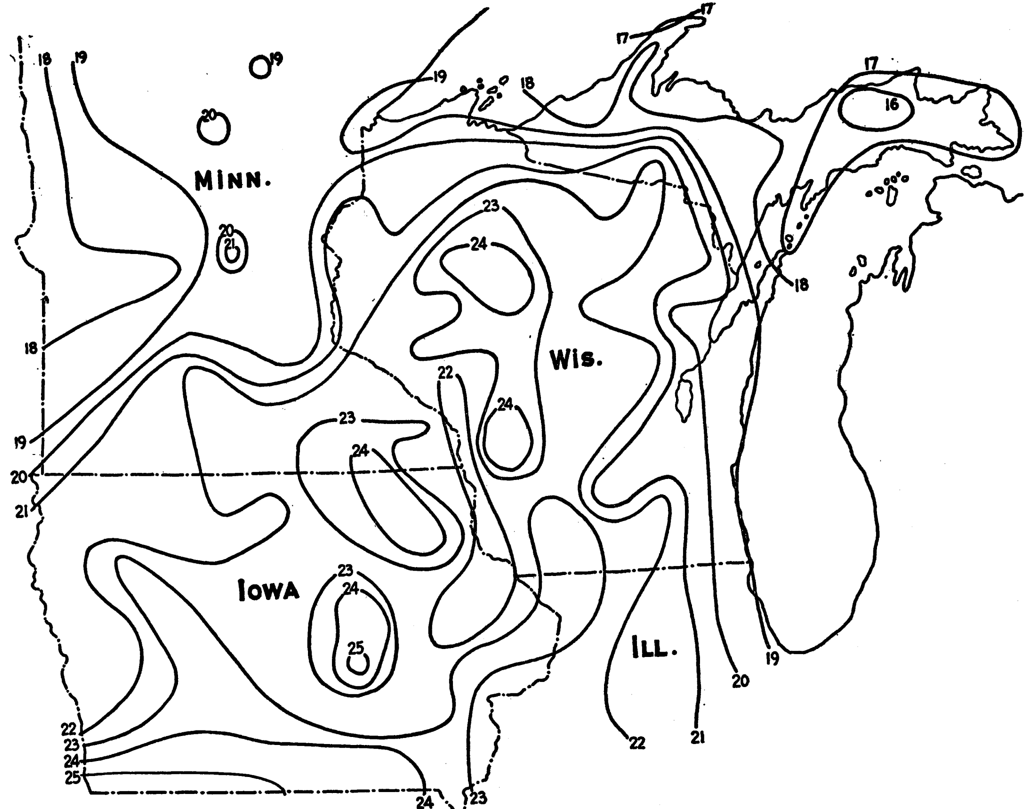
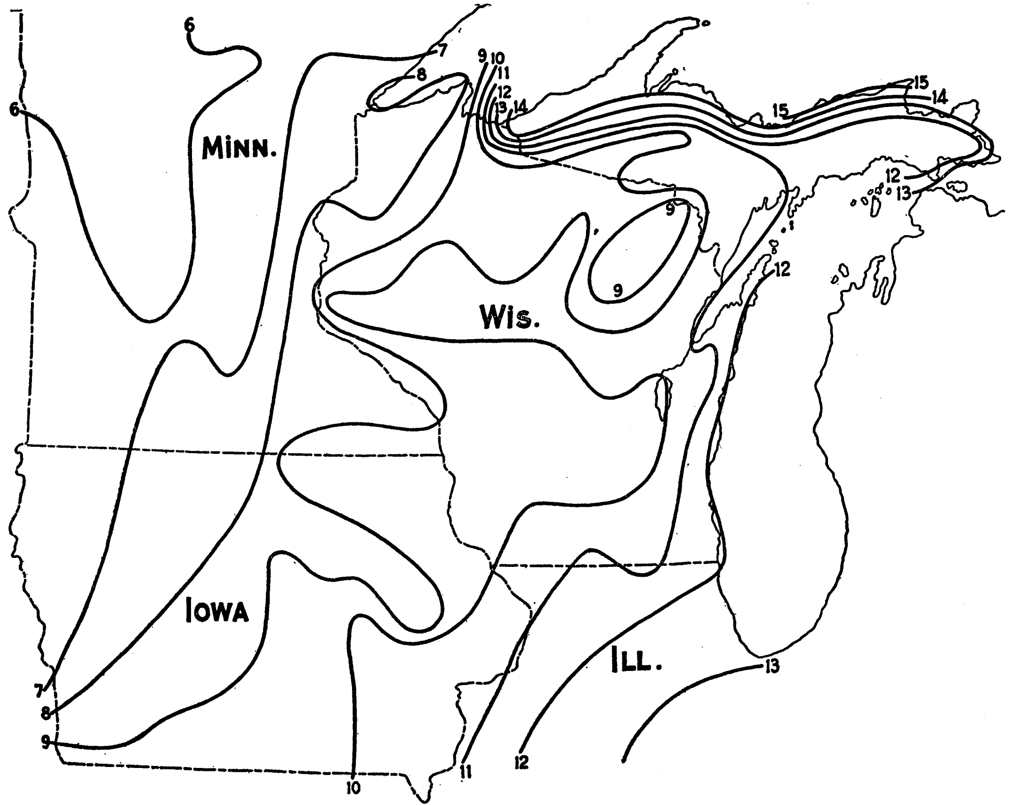


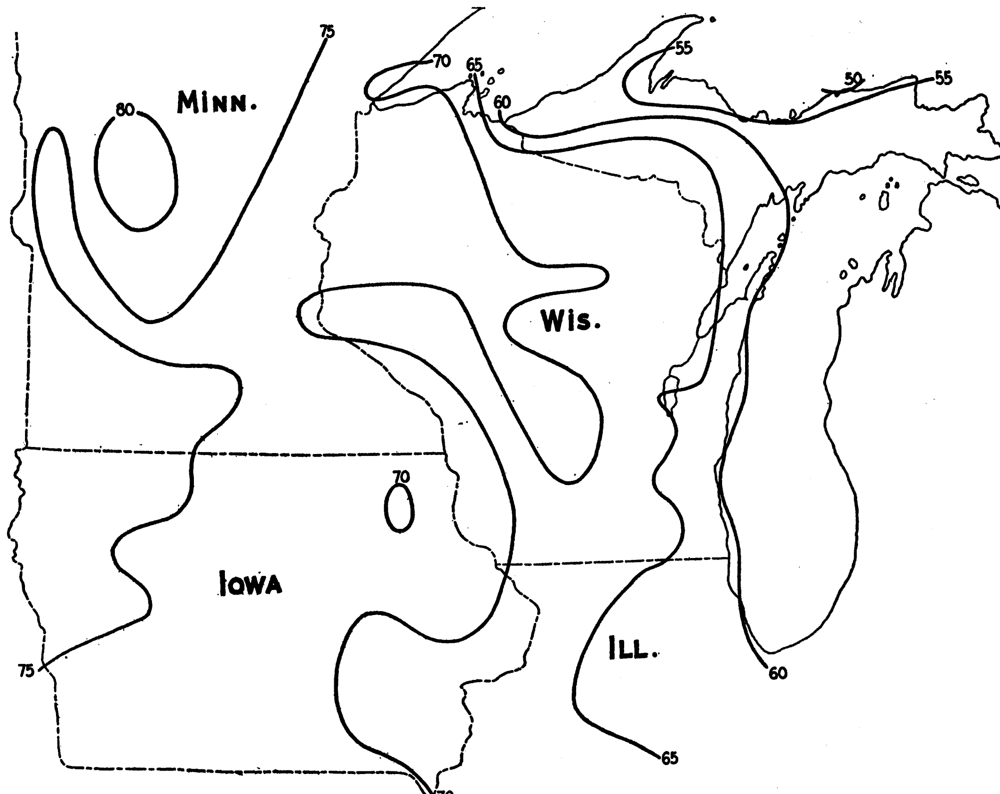
Map. 1. Average annual precipitation, 1897–1927 inc.



Map 2. Average warm season precipitation, April-September, 1897–1927 inc.



Map 3. Average cold season precipitation, October-March, 1897–1927 inc.



Map. 4. Percentage of the annual rainfall that falls in the six warmer months, April-September.

TRANSMISSION OF SOLAR RADIATION BY THE WATERS OF INLAND LAKES

E. A. BIRGE AND C. JUDAY

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

CONTENTS

1. *INTRODUCTION*

This paper deals with the amount of solar radiation delivered to a unit of horizontal surface at various depths in the upper water of lakes. The present paper states the results obtained and discusses their relation with similar observations made by other methods. The discussion of other conclusions which naturally come from the data is deferred to a later paper.

The study began in 1900 in a tentative way, employing a black-bulb thermometer *in vacuo* as the instrument. This instrument and its use have been described and illustrated (Birge '22, pp. 539–542). The rate of transmission was determined to a maximum depth of five meters and numerous observations were made in Lake Mendota during 1900 and 1901 and visits were made to eleven other lakes. None of these readings are used in the present paper, since they do not add to the knowledge obtained later. The results are in general agreement with those here reported and are from lakes also reported here.

After 1901 the study was discontinued until 1912, when the first pyrlimnometer was constructed. This instrument has been described and illustrated and, with certain improvements and modifications, it is still in full use. All observations reported in this paper have been made with it. Its essential part is a thermopile, whose electric current, when exposed to the sun's radiation, is measured by a galvanometer or millivoltmeter.

In the tables of this paper the amount of radiation received below the surface of the lake is reported as a per cent of the total radiation delivered to the thermopile when held horizontally just above the surface of the water at the time of observation. Radiation is stated in calories per square centimeter per minute.

The unit of depth usually employed is the meter. The coefficient of transmission is the per cent of radiation delivered at the upper surface of the meter stratum in question which is found at the lower surface of the stratum. This is called "the transmission," as a short title; a "transmission of 63 in the 1–2 m. stratum" means that the swing of the galvanometer at 2 m. is 63 per cent of the swing at 1 m. The coefficient of absorption of the stratum is the difference between the transmission and 100 per cent. In the example given the coefficient of absorption is 37 per cent. In this paper values are given in terms of transmission.

The transmission as stated in the tables is computed for zenith sun (see p. 517), and is stated to the nearest whole per cent. The transmission of the upper meter is given to the nearest tenth of one per cent, although there is no reason to think that much value attaches to the last figure. In computing results the fractional per cent was used and the final results were rounded off.

ACKNOWLEDGMENTS

We have received valuable aid from many persons, without whose assistance our work could not have been done. Especial thanks are due to the members of the department of physics, University of Wisconsin. From Professor C. E.

Mendenhall we have received much counsel; Professor J. R. Roebuck has determined the transmission of various glasses and ray filters; Professor L. R. Ingersoll has given unwearied aid and counsel in our innumerable difficulties. Mr. E. R. Miller, of the United States Weather Bureau, has constantly helped us in all the many matters relating to his department, and has also taken part in observations on lakes. In all mathematical questions constant recourse has been had to Professor H. W. March, of the department of mathematics, University of Wisconsin. We are indebted to Mr. F. E. Fowle of the Smithsonian Institution and Dr. H. H. Kimball of the U. S. Weather Bureau, Washington, D. C. for help and counsel.

The thermopiles with which we have worked and the galvanometer which we used until 1926 were constructed by Mr. J. P. Foerst of the University department of physics.

INSTRUMENTS

The pyrlimnometer has already been described and illustrated and the description need not be repeated. See Birge, '22, pp. 543–547. The modifications and improvements since 1922 are as follows:

1. In the original instrument the thermopile was made from iron-constantan couples. In 1926 a new thermopile was made from bismuth-silver couples. This gives for equal radiation about twice the swing of the iron-constantan apparatus. It was feared that the bismuth wire would prove too brittle for safe transportation, but no accident has happened, although the instrument has been carried several thousand miles over roads by no means exceptionally good. For carrying about the country it is placed on an inflated air-cushion in a basket.

2. The electrical current from the thermopile was measured by a D'Arsonval galvanometer (Birge, '22, p. 544). At first this was taken out in the boat, but while the instrument is not disturbed by motion parallel to the axis of the galvanometer, it is sensitive to motion at right angles to this axis. While, therefore, it was not difficult in a small lake to find places for observation which were sheltered from the wind, it was not possible to escape the effect of

swells caused by the movement of launches, etc. It was found better, therefore, to keep the galvanometer on shore and connect it with the boat by a long cable (l.c., p. 545). In 1926 the galvanometer was replaced by a Rawson millivoltmeter. This instrument has a scale of 100 divisions and four ranges, respectively 20 mv., 10 mv., 5 mv., and 2 mv. The swing of the needle on the 2 mv. range is about 2.5 times as great as on the 10 mv. These are the two ranges most used. Full sunlight at or near noon gives a swing on the 10 mv. range of about 80 divisions of the scale, equivalent to about 200 divisions on the 2 mv. range. The 2 mv. range is used for all readings in water at or below one meter, except in the case of the most transparent lakes, where it may be necessary to employ the 5 mv. range for the upper meters. This instrument is rapid in action and steady when used in a boat. Radiation can be followed with it as far down as one per cent of the amount in the air. In 1928 a more sensitive millivoltmeter was also used. This has a scale of 100 divisions and two ranges, 2 mv. and 0.333 mv. The last range gives six times the swing of the 2 mv. range and radiation can be followed correspondingly further. It is steady when used in the boat but the current is so feeble at considerable depths that the movement of the needle is slow. The instrument has been chiefly used to secure readings at moderate depths in highly colored lakes, in which radiation is very rapidly absorbed, and also for readings designed to follow the course of light of various colors, ray-filters being placed over the thermopile.

3. In the observations from 1913 to 1925 inclusive the thermopile had a hemispherical glass cover, not unlike that of the Callendar sunshine recorder or the Kipp and Zonen solarimeter. The bismuth-silver thermopile, constructed in 1926, was provided with a flat plate glass cover, so that ray-filters could be used with it. It appeared that the ratio between the reading in air and that at any given depth differed with the form of the cover, the hemispherical cover giving a decidedly lower ratio than the flat one. This led to a study of this ratio, the results of which are reported later.

4. In general it may be said that the instrument as now constructed serves well the purpose for which it was de-

signed. The radiation can readily be followed to a depth where the result is sufficient for general biological purposes in an inland lake. The apparatus is simple and easily handled; it can be easily transported; it is not heavy and can be used from a rowboat. Observations are made rapidly and with sufficient accuracy.

CALIBRATION OF INSTRUMENTS

There are two calibrations to be made on these thermopiles: (1) the value in calories of the scale readings, and (2) the ratio between the readings in air and in the water.

1. The first calibration is easily made. The station of the United States Weather Bureau at the University of Wisconsin keeps continuous records of radiation from sun and sky by means of a Callendar recorder. Very frequent comparisons of readings of the thermopile with those of the Callendar have been made. When the thermopile has a hemispherical glass cover no further comparisons are necessary. When a flat glass cover is used the effect of the angle between radiation and glass must also be determined.

2. The correct ratio between the reading in air and in the water is more difficult to determine. The thermopile is sensitive to radiation of every wave length, but water is highly selective in its power of transmitting radiation. The glass cover of the thermopile is also selective toward radiation and it behaves differently in air and in water. The solar radiation is mainly direct, from the sun, but a large fraction is diffuse, coming from the sky, and the two kinds behave differently both in regard to reflection and to transmission. Hence arises a complex condition, to which may be added the fact that the flat glass cover behaves differently from the hemispherical one both in air and in water.

The calibration was done with the flat cover, since experiment was more easy with that than with the curved surface. The standard depth of water used for comparison with the air is one meter, since at that depth the radiation coming from wave lengths beyond 0.762μ has been almost completely absorbed and no further consideration need be given to it. The following facts were determined: (a) the plate glass cover cuts off 18–19 per cent of the direct radiation at normal incidence in air. This was first determined with a Marvin pyrheliometer by Mr. Eric Miller, who is in charge of the United States Weather Bureau Station at the University. His results ranged from 17.8 to 18.9 per cent and averaged about 18 per cent. This result was used in the paper given at the meeting of the Geophysical Union in Washington, April 26, 1928 (Birge and Juday, '29, p. 64). This work was done not long before going into the field for the summer of 1928 and under this condition we did not wish to dismount any of the thermopiles for the study. After returning from the field one of the iron-constantan thermopiles was uncovered and mounted as a pyrheliometer. It appeared from numerous experiments that the plate glass cut off an average of about 19 per cent of the direct radiation rather than 18 per cent as found in the Marvin instrument. This value has been used in all results except those already reported at Washington. Since the difference is small and quite within the ordinary variation of sunshine from minute to minute, it did not seem necessary to correct the figures already given.

The behavior of the cover below the surface of the water could not be directly observed since it is not possible to use an uncovered thermopile in the water. Determination of the transparency of the glass showed that there is no appreciable absorption of radiation at wave lengths which are left in the water at a depth of one meter. At any rate, no more would be absorbed than by clear water of the same thickness as the glass, so that no special allowance need be made for it. The refractive index of the glass is 1.52, corresponding to a reflection of 4.26 per cent of radiation at normal incidence. This amount would not exceed 5 per cent until the angle of incidence exceeds 40°.

The result for the plate glass used in water at one meter or deeper is as follows: little or no allowance need be made for reflection from the upper or glass-water surface of the cover; there is a reflection of 4.26 per cent or somewhat more from the lower or glass-air surface of the cover; little or no allowance need be made for absorption of radiation in passing through the glass. It was therefore determined to allow a total loss of 5 per cent for the effect of the glass cover in water at depths of one meter or more. At smaller depths there would be a greater loss corresponding to the depth and to the amount of long wave radiation left in the total; but in no case would the absorption of such radiation by the glass exceed that of a corresponding thickness of water, so that the allowance of 5 per cent will still be reasonable. Thus the reading of the thermopile in air is determined as 81 per cent of its true value and that in water as 95 per cent of its value; and the observed swings of the millivoltmeter are corrected accordingly.

It will be noted that this calibration deals with the direct radiation only, diffuse radiation being neglected. No way was found of dealing with radiation from the sky separately from that direct from the sun. The amount of diffuse radiation reflected from the glass cover and from the surface of the water is different from the amount of direct radiation reflected. The mean path of diffuse radiation in water is also greater than that of direct, so that a greater per cent will be absorbed in reaching the depth of one meter below the surface. Thus the percentage stated as present at one meter can not be exact and is probably somewhat too great. The error can not be very large, however; and even a considerable error in determining the amount at one meter makes very little difference in the general result.

The hemispherical cover was calibrated by comparison with the results reached by experiment with the plate glass cover. The curved surface does not lend itself to direct experiment as well as the flat one. One of the iron-constantan thermopiles was repeatedly compared with the other, when both were provided with plate glass covers. Then one was furnished with a hemispherical cover and in this condition was compared with the other. Its readings were also compared with those taken with the plate glass cover by alternately placing the two covers on the same thermopile. In this way the difference between the two covers in air was determined. For comparison in the water the two thermopiles with different covers were mounted in the same frame and were read alternately at different depths in the water of Lake Mendota. The result was to show that the hemispherical cover gave higher readings in air and lower in water than the flat cover. This would be expected since the form of the dome and the thinner glass of which it is made would allow a greater penetration of radiation in air. In the water the concave lens caused by the water-glass surface would lower the reading.

It was found that the readings of the thermopile with the hemispherical cover could be brought into agreement with the corrected readings of the other instrument, by dividing the reading in the air by 1.5. All observations made between 1913 and 1925, inclusive, have been thus adjusted.

This adjustment of readings concerns only the relation of the reading in the air with that in the water. Either instrument gives the same ratio between readings both of which are made in the water. Thus the transmission in water is the same with either form of thermopile; adjustment is needed to carry these readings in water over into the air so as to determine in calories the value of the transmitted radiation.

Adjustment for Altitude of Sun

The amount of radiation in the water of the lake is measured at certain definite distances below the surface, one meter, two meters, etc. The distance through which radiation will have traveled in order to reach this depth varies with the altitude of the sun, and since the distance varies, the amount of absorption varies correspondingly. If the sun is only 5° above the horizon its direct rays pass through 1.505 m. of water in reaching the depth of one meter below the surface. They have passed through one meter of water at the depth of about 66.4 cm. This is an extreme case and is a condition under which observations on the sun would not be made. But many observations will be made when the sun is at altitudes between 40° and 50° and the radiation has passed through one meter at depths between 82 cm. and 88 cm.

In all cases therefore, it is advisable to reduce observations to a standard altitude of the sun and the best altitude is that of a zenith sun, since from this the situation at any other elevation can be readily derived. The method employed is to plat the observations, reduced to percentages of radiation in air, on coordinate paper, to join the points thus ascertained by a line, and to mark on this curve the depths corresponding to the successive cosines of the angle of refraction. Mathematical methods may also be used. (See Shelford and Gail, '22.)

In practice the altitude of the sun is taken from a large diagram on which is drawn a series of curves giving the altitude for each half hour between 8:30 a. m. and 3:30 p. m. and from April 1 to October 15. The altitude for intermediate times, such as 9:48 a. m. is estimated from the distance between the curves. No attempt is made to get the altitude closer than the nearest degree. The corresponding distance to be employed is taken from a diagram in which the cosine of the angle of refraction in water is platted against the altitude of the sun. This is easily read to 0.1 cm., but no attempt is made to use distances smaller than one centimeter.

As coordinate paper for platting transmission curves there can be used either standard paper or semi-logarithmic paper. The latter is the more convenient since the angle made by the transmission curve with the lines representing depth or per cent varies only as the transmission per cent varies, while in standard cross section paper this angle depends also on the number of units gained or lost. (See figs. 2 and 3.) Thus the curve comes to run nearly parallel to the depth lines near the surface when many units are lost by absorption; and when the radiation is reduced to a small amount the curve runs nearly parallel to the per cent lines, although in each case the transmission may be practically the same. It is impossible to mark the curve accurately if drawn on ordinary coordinate paper.

An illustration of the effect of reducing observations to zenith sun may be taken from two series made on Lake Mendota, July 10, 1916, as given in table 1 and figure 1. The first series was made at 12:20–12:40 p. m. and the second at 4:20–4:35 p. m. In the first case the sun's altitude was 68.5° and the corresponding cosine of the angle of refraction is 96; at 4:30 the altitude was 31.8°, whose cosine is 77. No readings were taken above the depth of one meter and the transmission was fairly uniform between one meter and three meters. The percentages found by observation have been platted and the transmission curves have been marked for the corresponding cosines (fig. 1). The two curves are quite different but when adjusted for zenith sun they show that the transmission was practically identical for the two series.

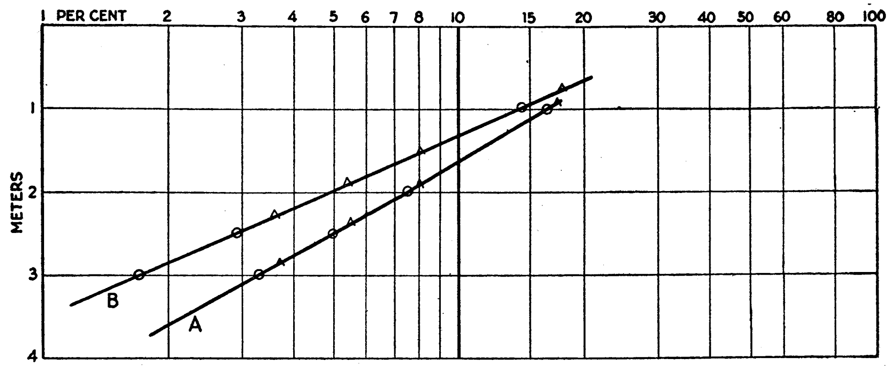


FIG. 1. Observations on Lake Mendota, July 10, 1916. For details see text. Small circles mark the percentages observed. An inverted V marks percentages as corrected for zenith sun. In the noon series (A) the radiation passes through one meter of water in the vertical distance of 96 cm.; at 4:30 (B) the corresponding distance is 77 cm. The curves are marked accordingly and the dots show that substantially equal percentages of radiation are transmitted by each meter of water, if zenith sun is assumed; while the direct observations seem to show a much lower transmission in the afternoon.

TABLE 1. *Lake Mendota, July 10, 1916*

Depth, meters,	Per cent, Noon Observed	Per cent, Noon Zenith sun	Per cent, 4:30 p. m. Observed	Per cent, 4:30 p. m. Zenith sun
Surface	100	100	100	100
1.0	16.2	16.7	14.1	17.7
2.0	7.5	8.2	5.0	8.2
2.5	4.9	5.5	2.9	5.4
3.0	3.3	3.7	1.7	3.5

The transmission in the 1–2 m. stratum was 47 at noon and 35 at 4:30; in the 2–3 m. stratum it was 44 and 34, respectively. When adjusted to zenith sun the transmission became 48 and 47, and 44 and 43, or substantially the same in both cases. At noon the incident radiation would have been reduced to one per cent at the depth of 4.5 m., at 4:30

the same per cent would have been found at 3.5 m. When adjusted for zenith sun both series gave 4.8 m. as the depth for one per cent.

In this case, as in others, all radiation is treated as coming direct from the sun. No account is made of diffuse radiation because it was impossible to determine the amount of this under the conditions of observation. It is even less possible to determine how the origin of the diffuse radiation is distributed over the sky and thus determine its average angle of incidence on the water. The omission of this factor makes the cosine somewhat larger than the true value, and correspondingly decreases the correction applied to the percentages observed at any given depth.

Thus in the general tables the results of observation are corrected for zenith sun and on the assumption that all radiation is direct from the sun.

2. *OBSERVATIONS ON LAKES*

There are reported in this paper 36 series of observations in the upper water of Lake Mendota and 96 series on 55 other lakes. Of these lakes 26 are in South eastern Wisconsin, 25 in Northeastern Wisconsin, 3 in New York, and 1 in Iowa. The results are given in table 11 at the end of this section; the general results are summarized and illustrated in the following pages.

GENERAL RESULTS

DATA

Table 2 and figures 2 and 3 show the transmission of radiation through the water of a series of lakes which illustrate all types found in Wisconsin. Table 2 gives four series of data from each lake, in order to illustrate the kind of data obtained and the methods of handling them. The first line under each lake gives the swing of the galvanometer or millivoltmeter, stated in divisions of the scale and adjusted as described on p. 515; the second line states the per cent of radiation found at each depth, taking the incident

TABLE 2. *This table gives data for a selected series of lakes, ranging from the most opaque to the most transparent. For explanation, see text, p. 520. For transmission in these lakes see tables 4, 10, and 11. "Observed data" are the swing of the galvanometer in divisions of the scale,, adjusted to true values; the relation between "zenith sun" and "mean sun" was computed for Lake Mendota and the result is applied to all lakes. See p. 545.*

Depth, m.	Air	0.25	0.50	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Beasley Lake, Sept. 5, 1918. Cosine, 85															
1. Observed data	101	45.6	32.3	21.0	14.8	11.2	8.1	3.3	1.9	0.9	------	------	------	------	------
2. Per cent, observed	100	45.0	32.0	20.8	14.7	11.1	8.0	3.3	1.9	0.9	------	------	------	------	------
3. Per cent, zenith sun	100	------	35.0	24.0	17.6	12.6	9.4	4.5	2.8	1.9	------	------	------	------	------
4. Per cent, mean sun	100	------	33.0	21.5	15.0	10.9	8.1	3.3	2.0	1.0	------	------	------	------	------
Blue Lake, Sept. 4, 1918. Cosine 88															
1. Observed data	135	59.6	50.1	37.5	------	26.2	------	18.6	13.2	10.0	8.2	6.0	4.6	3.3	------
2. Per cent, observed	100	44.1	37.1	27.8	------	19.4	------	13.8	9.8	7.4	6.1	4.4	3.4	2.4	------
3. Per cent, zenith sun	100	44.5	38.0	29.8	------	21.4	------	15.7	11.7	8.8	6.9	5.5	4.4	3.5	2.6
4. Per cent, mean sun	100	------	------	27.5	------	14.5	------	13.6	9.7	7.2	5.6	4.3	3.3	2.5	1.9
Crystal Lake, Mean results															
3. Per cent, zenith sun	100	------	------	37.5	33.0	28.9	25.8	23.2	18.1	14.6	12.0	10.3	8.6	7.2	5.9
4. Per cent mean sun	100	------	------	36.0	31.2	26.8	23.5	20.5	15.7	12.3	10.4	8.5	6.8	5.5	4.4
Crystal Lake, July 6, 1926. Cosine 92															
1. Observed data	111	60.0	53.7	42.1	34.7	31.6	28.4	25.3	20.0	16.5	14.7	12.6	11.6	10.0	------
2. Per cent, observed	100	54.1	48.4	38.0	31.3	28.5	25.2	22.8	18.0	14.9	13.2	11.3	10.5	9.0	------
3. Per cent, zenith sun	100	55.0	49.1	39.7	33.5	28.5	26.0	23.0	19.2	16.2	13.8	12.3	10.6	9.6	8.7
4. Per cent, mean sun	100	53.0	46.8	37.3	27.1	27.6	24.3	21.2	16.7	14.3	12.3	10.5	9.3	8.3	7.5
Green Lake, Aug. 5, 1923. Cosine 86															
1. Observed data	96	53.8	36.0	27.0	21.9	17.0	13.2	11.0	7.3	5.1	3.5	2.1	1.6	0.9	------
2. Per cent, observed	100	56.0	37.5	28.1	22.8	17.7	13.7	11.5	7.6	5.3	3.6	2.2	1.6	0.9	------
3. Per cent, zenith sun	100	59.0	39.0	30.6	25.0	20.5	17.0	13.7	9.8	7.2	5.0	3.6	2.5	1.8	1.3
4. Per cent, mean sun	100	53.0	36.0	28.8	22.8	18.0	14.5	11.8	8.0	7.4	3.6	2.4	1.6	1.1	0.8

TABLE 2—Continued

Depth m.	Air	0.25	0.50	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0	7.0
Lake Mary, July 11, 1928. Cosine 90												
1. Observed data	174	36 8	16.8	6.9	2.8	----	----	----	----	----	----	----
2. Per cent observed	100	21.1	9.7	4.0	1.6	----	----	----	----	----	----	----
3. Per cent zenith sun	100	24.5	12.0	4.7	2.1	1.1	----	----	----	----	----	----
4. Per cent, mean sun	100	15.0	8.9	3.8	1.0	----	----	----	----	----	----	----
Lake Mendota, May 29, 1928. Cosine 90.												
1. Observed data	200	94.0	77.0	55.0	----	31.0	----	20 0	12.2	7.5	----	----
2. Per cent, observed	100	47.0	38.5	27.6	----	15.5	----	10 0	6.1	3.8	----	----
3. Per cent, zenith sun	100	48.0	40.0	30.0	----	17.8	----	11.4	7.5	4.9	----	----
4. Per cent, mean sun	100	----	----	27.0	----	15.2	----	9.3	5.6	3.5	----	----
Lake Mendota, May 20, 1926. Cosine 92.												
1. Observed data	654	221	177	90	46	26	18.4	9.5	3.2	----	----	----
2. Per cent, observed	100	33.8	27.1	13.8	7.0	4.0	2.8	1.45	0.5	----	----	----
3. Per cent, zenith sun	100	----	26.0	14.5	7.6	4.8	3.0	1.85	0.7	----	----	----
4. Per cent, mean sun	100	----	----	12.5	6.5	3.6	2.3	1.2	0.5	----	----	----
Lake Mendota, Mean												
3. Per cent, zenith sun	100	44.0	33.1	20.7	13.8	9.7	6.8	4.8	2.4	1.2	----	----
4. Per cent, mean sun	100	----	----	18.2	11.5	8.0	5.2	3.5	1.5	0.7	----	----
Turtle Lake, Aug. 30, 1918. Cosine 84.												
1. Observed data	82.0	18.6	10.7	6.6	3.0	1.4	0.8	----	----	----	----	----
2. Per cent observed	100	22.7	13.0	8.1	3.7	1.7	0.9	----	----	----	----	----
3. Per cent, zenith sun	100	----	24.0	10.0	5.5	2.8	1.5	----	----	----	----	----
4. Per cent, mean sun	100	----	23.3	8.2	4.0	1.8	0.9	----	----	----	----	----
Weber Lake, Aug. 13, 1927. Cosine 91.												
1. Observed data	184	81.1	74.0	61.0	51.0	41.0	35.0	30.0	23.7	19.0	----	----
2. Per cent, observed	100	44.0	40.2	33.1	27.7	22.5	19.0	16.3	12.9	10.3	----	----
3. Per cent, zenith sun	100	44.5	41.0	34.0	28.5	24.6	20.2	17.7	13.8	11.2	----	----
4. Per cent, mean sun	100	----	----	32.5	26.7	22.1	18.5	15.7	12.0	9.3	----	----

radiation in air as 100; the third line gives the per cent as corrected for zenith sun. These last are the values used in the regular tables and diagrams. The transmission for each meter stratum is derived from them by dividing the

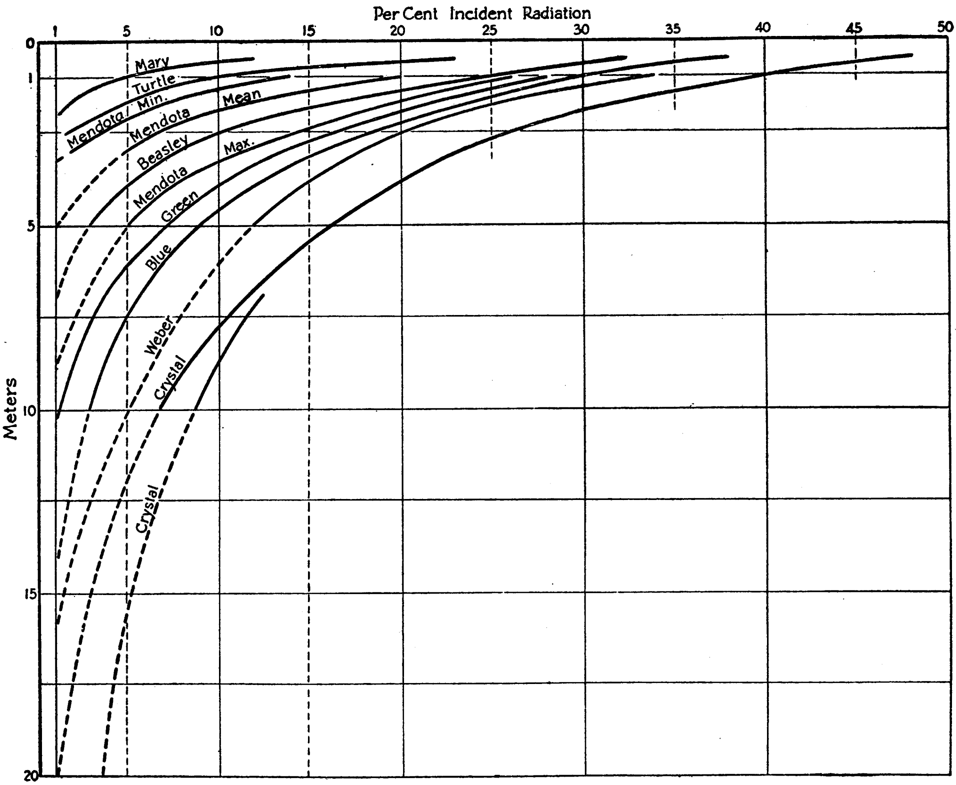


FIG. 2. Transmission curves for various lakes. In general the curves are started at one meter depth, but in a few cases begin at 50 cm. in order to show the course of the curve in the upper water. They are carried down in the intersection with the line indicating one per cent of incident radiation. Where the extension is long the accuracy is correspondingly uncertain.

In a diagram platted on regular coördinate paper the length of the abscissa to the intersection with any transmission curve indicates the amount of radiation left at the depth of the abscissa.

per cent at the bottom of any stratum by that at its top. This transmission for these lakes is stated in tables 10 and 11. The fourth line gives the values for "mean sun" as defined on p. 545. These may be used in computing the num-

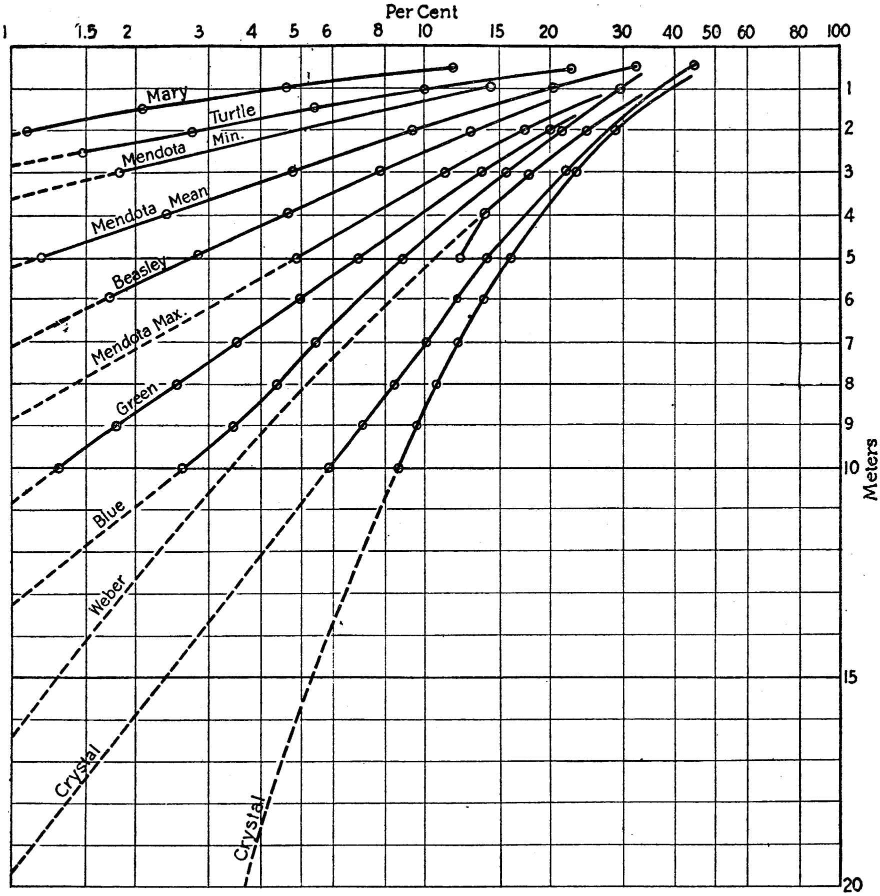


FIG. 3. The same transmission curves as those in figure 2, but platted on semi-logarithmic paper. This platting shows the rate of transmission and its changes in different strata much more accurately than the regular coördinate paper; but it does not show to the eye the amount of radiation left at various depths. Note that in the most opaque lakes the transmission curve is practically a straight line from 50 cm. down, indicating a constant transmission. In Crystal Lake the curve is constantly deflected toward the right, indicating a constantly increasing transmission. Blue Lake and Weber Lake show variations either accidental or systematic. Weber Lake, between 4 m. and 5 m. shows a marked increase of transmission, probably accidental. The case is inserted to illustrate this very common occcurrence. Blue Lake seems to show an increasing transmission between 5 m. and 9 m. with an accidental drop between 9 m. and 10 m.

ber of calories delivered by direct insolation at any given depth during the warming period, April–August, assuming that conditions are not dissimilar to those at Madison.

Figures 4 and 5 contain similar transmission curves for a number of other lakes reported in the general tables. Figure 6 shows maximum, minimum, and mean curves for a moderately transparent lake and for an extremely transparent one; similar curves for Lake Mendota, a relatively opaque lake, are given in fig. 3. Figure 7 plats the transmission for a series of lakes, in order to show its systematic and accidental variations. Figure 8 shows transmission curves in the upper two meters of several lakes.

In figures 2 and 3 the transmission curves are platted on two types of co-ordinate paper, fig. 2 on standard paper and fig. 3 on semi-logarithmic paper. The same facts are shown on each diagram so as to bring out the relation of the two types of platting. The standard paper gives to the eye the better idea of the amount of radiation delivered at different depths, and the semi-logarithmic paper gives a more definite notion of the rate of transmission.

Results

Transmission is determined by three main factors: (1) the selective action of water, which is transparent to short wave radiation and opaque to long waves; (2) the selective effect of stain which acts more strongly on the short wave radiation and is effective in proportion to the amount and kind present; (3) the action of suspended matter—organic and inorganic—which offers more obstruction to short wave radiation, but is not definitely selective.

Thus the selective action of water is a constant factor in all lakes; that of stain is very variable as between different lakes, and somewhat variable in the same lake at different times. It is usually, but not always, the same in the same lake at different depths of the same series. The influence of suspended matter may differ widely in different lakes, in the same lake at different times, and at different depths in the same lake at the same time. In eutrophic lakes its influence is very great and often dominant; in lakes with little plankton it is less and stain or water itself may be more important factors in reducing radiation. In the surface meters there is more plankton, and to this fact is due part of the relatively low transmission in the 1–2 m. stratum. The presence of an actual or potential scum of algae in the surface water may add greatly to the absorption in the upper meter (Lake Kegonsa, table 11). If a crop of algae or other suspended matter is settling, the surface water may be much more transparent than that below (Marl Lake).

Where high stain and much suspended matter combine to obstruct radiation, the transmission is low and practically constant at all depths. When the transmission curve is platted on semi-logarithmic paper it is indistinguishable from a straight line, perhaps from the depth of 0.5 m. on. In most lakes, however, the transmission of the 1–2 m. stratum is decidedly lower than that of the strata below; but in the highly eutrophic lakes of Southeastern Wisconsin there is but little rise in transmission after passing the depth of 3 m. This situation holds in general for lakes whose transmission does not exceed 60. Where transmission reaches 70, as in Green Lake, it is apt to increase up to 4 or 5 m. (table 10) and to remain steady thereafter, showing only accidental variations in the deeper water down to 10 m. When transmission reaches 80 or more, as in Crystal Lake, the increase may continue in some cases as far as observation has gone, i. e. up to 10 or 11 m. (see table 10) and at that depth transmission may exceed 90. For illustrations both of the uniformity of transmission and of its increase with depth, see figs. 3–6 and fig. 8.

Table 2 and figures 2 and 3 illustrate the principles of transmission in lakes. For illustrations we will confine our attention to the third line, zenith sun. This is derived from the observed per cent, as shown in fig. 1, and the fourth line, mean sun, is derived from zenith sun as shown in fig. 9.

The great loss of radiation in the upper meter is obvious. No lake has at the depth of one meter as much as 40 per cent of incident radiation. Some of the loss is due to reflection, but most comes from absorption in passing through the water. Pure water transmits through the first meter less than 50 per cent of incident radiation, the amount varying with the altitude of the sun and the quantity of precipitable water in the atmosphere. Thus a large part of the loss of radiation in the first meter comes from water itself. In Crystal Lake this is the main source of loss, and most of the remainder is due to suspended matter. In perhaps all of the other lakes stain plays a larger or smaller part in reducing the radiation. No other lake much ex-

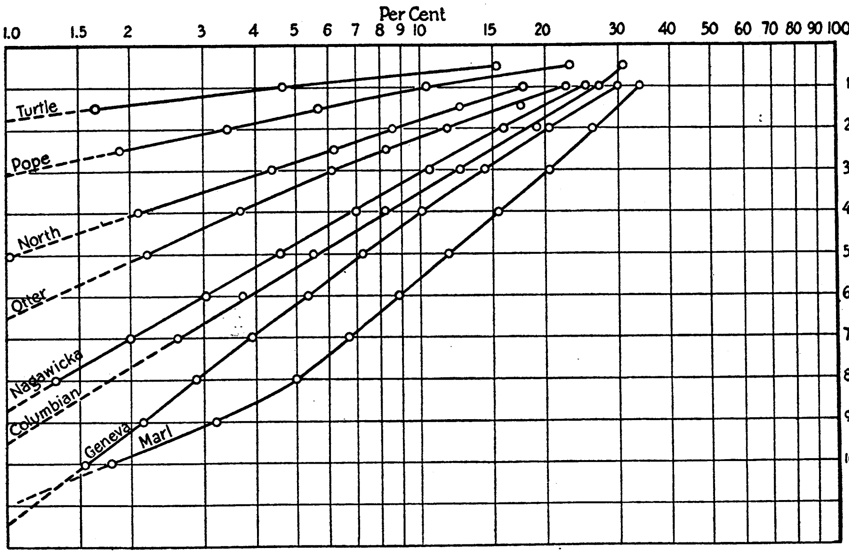


Fig. 4. Transmission curves, chiefly from southeastern lakes. Turtle Lake from the Northeastern District has a lower transmission than any southern lake visited. The curve for Pope Lake in the Southeastern District is practically identical with that of Allequash Lake. These lakes are slightly below the minimum for Lake Mendota, and Nagawicka Lake has a transmission practically identical with the maximum of Mendota. Columbian Lake lies between the maximum of Mendota and the regular curve of Green Lake. The curve of Marl Lake approaches that of the most transparent lakes in its upper part and shows a great decline of transmission at 8 m. and below.

ceeds 30 per cent at the depth of one meter, Weber Lake alone going as high as 34 per cent. Both Blue and Weber lakes are recorded with zero color in the tables, and no doubt suspended matter has more influence than stain in them.

At the other end of the series are Turtle and Mary lakes, in which both stain and suspended matter combine to reduce the amount of radiation at one meter to 10 per cent or less. In Turtle Lake stain alone may bring down the transmission of the first meter as low as 11 per cent. In Devils Lake and Green Lake stain plays a minor part and the variations shown in Green Lake in fig. 7 depend mainly

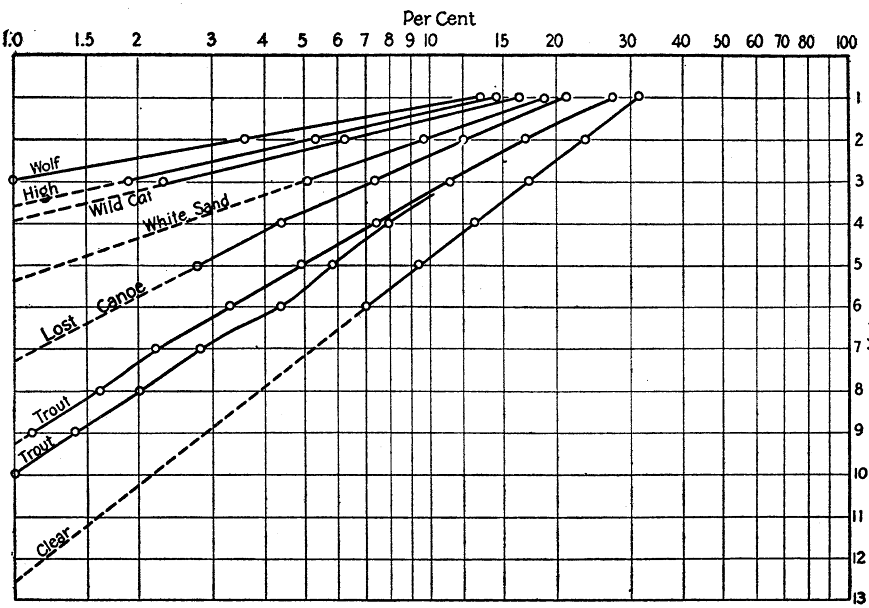


FIG. 5. Transmission curves for lakes from the Northeastern District. Wolf, High, and Wild Cat lakes have a fairly high stain and much plankton; they come within, or (Wolf) just outside the limits of Lake Mendota. White Sand and Lost Canoe lakes are near the mean for Mendota. Trout Lake lies between Green Lake and the maximum for Mendota. Clear Lake is close to Blue Lake (fig. 3) Two curves for Trout Lake are given, one a regular one and the other with accidental irregularities. Lost Canoe Lake shows a similar decline of transmission between 4 m. and 5 m.

on variations in plankton. The same is, of course, true of the variations in Crystal Lake in fig. 7.

The transmission curves for Lake Mendota (figs. 3 and 10) give an instructive picture of conditions in a lake with low stain (color 6–10 on the platinum–cobalt scale) and with large and varying amounts of plankton. The per cent at one meter may be as high as 30, thus closely approaching Green Lake. It may be as low as about 14, not far above Lake Adelaide (table 11) with its color of 25 or more. The effect of plankton is even more strongly shown in Lake Kegonsa (table 11), which, with a color close to that of Mendota had at one meter only 7.2 per cent of the radiation present at the surface. Within the range shown by Mendota come the great majority of the southeastern lakes and

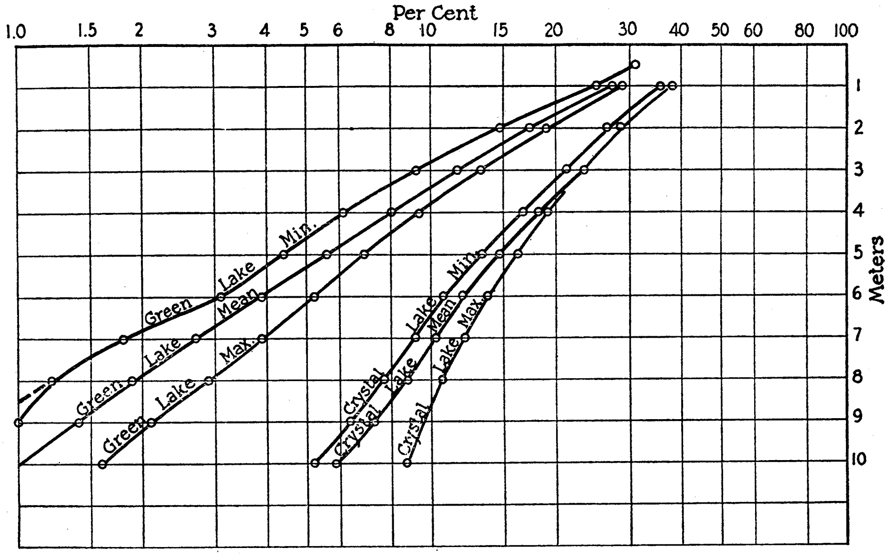


FIG. 6. Transmission curves for Green and Crystal lakes. These show the mean, minimum, and maximum curves for a lake with moderately high transmission and one whose transmission is exceptionally high. Corresponding curves for Lake Mendota are given in fig. 3. The curves for Green Lake are from Aug. 22, 1922 and Aug. 4, 1919. Those for Crystal Lake are from Aug. 17, 1926 and July 6, 1926. See table 10.

many of the northeastern. One such lake—Beasley—is platted on figs. 2 and 3, in order to illustrate this fact.

Table 2 and the accompanying figures show that in the less transparent lakes the radiation is followed to the depth where one or two per cent of the observed incident radiation is left. No lake is studied below 10 m. and at this depth as much as 4 to 8 per cent remains in Crystal Lake, but not much more than one-half that maximum in any other. In all diagrams the transmission curve has been prolonged until it intersects the line indicating one per cent of incident radiation. This prolongation has a very different length in the several cases. Often the lowest observed point is close to one per cent and in other cases the line must be extended through several meters. Where the distance is short and the curve on semi-logarithmic paper is practically a straight line, the extension may be confidently made. Its precise course is uncertain in proportion to its length and to the nature of the curve. Where a noteworthy change in transmission occurs with the observation at the greatest depth, it is doubtful whether the line should follow the general trend of the curve or the altered direction. For this note the curves for Blue and Weber lakes in fig. 3. So, also, if transmission is still increasing at the deepest observation—as in Crystal Lake—it is not certain how long increase will continue or how far it will go. Approximate accuracy only can be assured in such cases. In most of the lakes in the list the general situation is clear enough before the last reading is passed.

The depth at which one per cent of incident radiation can be delivered by the sun varies from about 2 m. to more than 20 m. The latter distance is reached only by Crystal Lake among those which have been studied. In one case one per cent would not have been reached at a depth less than 30 m., if conditions were the same below 10 m. as they were above that depth. Since the depth of the lake is 21 m., more than one per cent of the radiation would have been present in the bottom water, assuming a sun in the zenith. This was a condition of exceptional transparency; in other cases in the same lake radiation would have been reduced to one per cent at a depth of 16 m. or 18 m., the difference depending on the amount of plankton present.

From the diagram it is also possible to discover the thickness of the stratum of water below the surface meter or two, which will reduce radiation to one-tenth of the quantity delivered to its upper surface. The thickness of this stratum varies from a minimum of 1.4 m. in Lake Mary to more than 12 m. in Crystal Lake; it perhaps reaches nearly 20 m. in exceptional cases in the latter lake. In Lake Mendota it ranges from 2.3 to 5.6 m. with a mean of 3.3 m.;

and this range would include the cases of the ordinary eutrophic lakes, especially those of the southeastern district. Green Lake, with about 7 m., and Blue Lake with 8.7 m. illustrate the cases of the more transparent lakes, having relatively little plankton and little stain.

In the relatively opaque and shallow lakes there would be small chance of serious error if these figures were applied to the deeper water of the lakes. Beasley lake, for instance, had one per cent of incident radiation left at 7.1 m. and radiation is reduced to one-tenth of its surface value by passing through a stratum 4.6 m. thick. We are fairly justified in applying this figure to the remainder of the lake, which is 15 m. deep. At this rate the value of the radiation at the bottom would be 0.0002 of the incident radiation or 2×10^{-4}. In Lake Mendota the radiation might be followed down in the same way. The curve for mean transmission shows one per cent just below 5 m. This would bring one-tenth of one per cent about 8.5 m. and reduction would continue at the rate of 90 per cent in 3.5 m. to the bottom at about 24 m. In the case of the maximum observation the depth at which one per cent is reached is 8.9 m. and an additional stratum 5.6 m. thick is needed to reduce this value to one-tenth of one per cent. Figure 9 shows the situation in Lake Mendota, giving the data for both zenith sun and mean sun. The curve for filtered water in this lake is also platted.

These diagrams well illustrate the fact to which Poole and Atkins call attention ('28, p. 475); viz. that the decrease in radiation with depth goes up very rapidly as the per cent of transmission decreases, since this decrease makes the radiation fall off in a geometrical ratio. Thus at one meter the amount of radiation in the lake ranges from 0.14 to 0.28—a two-fold ratio. At 10 m. the maximum shows that there is left 6×10^{-3}, while the minimum is only 2×10^{-5}. At 5 m. the maximum shows nearly 0.05, while the minimum has only 0.0026, or practically one-sixteenth as much.

The following table summarizes the most important facts regarding the lakes shown in figures 2 and 3. They will also be found listed in table 11, where the transmission in the several meter strata is given; and the more transparent lakes are also found in table 10.

TABLE 3. *Summary of data regarding lakes shown in figures 2 and 3*

Lake	Transparency, meters	Color	Per cent at one meter	Average transmission	One per cent at meters	Stratum transmitting 10 per cent meters
Mary	1.5	118	4.7	24	2.0	1.4
Turtle	2.7	74	10.0	28	2.8	1.8
Mendota, mean	3.1	8	20.7	50	5.2	3.3
Mendota, max.	5.5		30.3	66	8.9	5.6
Mendota, min.	1.4		13.8	38	3.6	2.3
Beasley	5.3	8	25.8	60	7.1	4.6
Green	3.6	6	30.6	65–70	10.8	6.9
Blue	7.2	5	29.8	75–80	13.3	8.7
Crystal, mean	10.8	0	37.5	81	19.7	12.5
Crystal, max.	13.0	0	39.7	80–91	Ca. 34.0	Ca. 20.0

Figure 7 shows for a few lakes the coefficients of transmission platted on a large scale, so as to illustrate various details. Among these are: the marked rise in transmission in the 1–2 m. stratum as compared with the 0–1 m. stratum, and the smaller rise when the 2–3 m. stratum is reached; the tendency toward a uniform rate of transmission in almost all cases, together with a gradual systematic rise in the upper strata of the more transparent lakes; the kind and amount of accidental variation which may be expected in such observations.

In the extreme case—Crystal Lake—transmission must nearly reach the maximum for inland lakes, since at 10 m. it is above 90. The transmission of Blue Lake seems to be steady at about 80. Marl Lake, very transparent near the surface, shows a marked and progressive loss of transmission in the deeper water, which is probably due to suspended matter which had settled out of the surface water. Green Lake offers a typical case of a moderately high transmission—going above 70—together with the accidental variations which are often found in such a series. Something of the same sort is shown by Beasley Lake, on a lower level of transmission. Spider Lake has a very low transmission in the upper meter, due to abundant plankton. The same fact causes uniformly low transmission below two meters. The color of the lake water is low (8) and would not of itself cause a low transmission. Compare in this

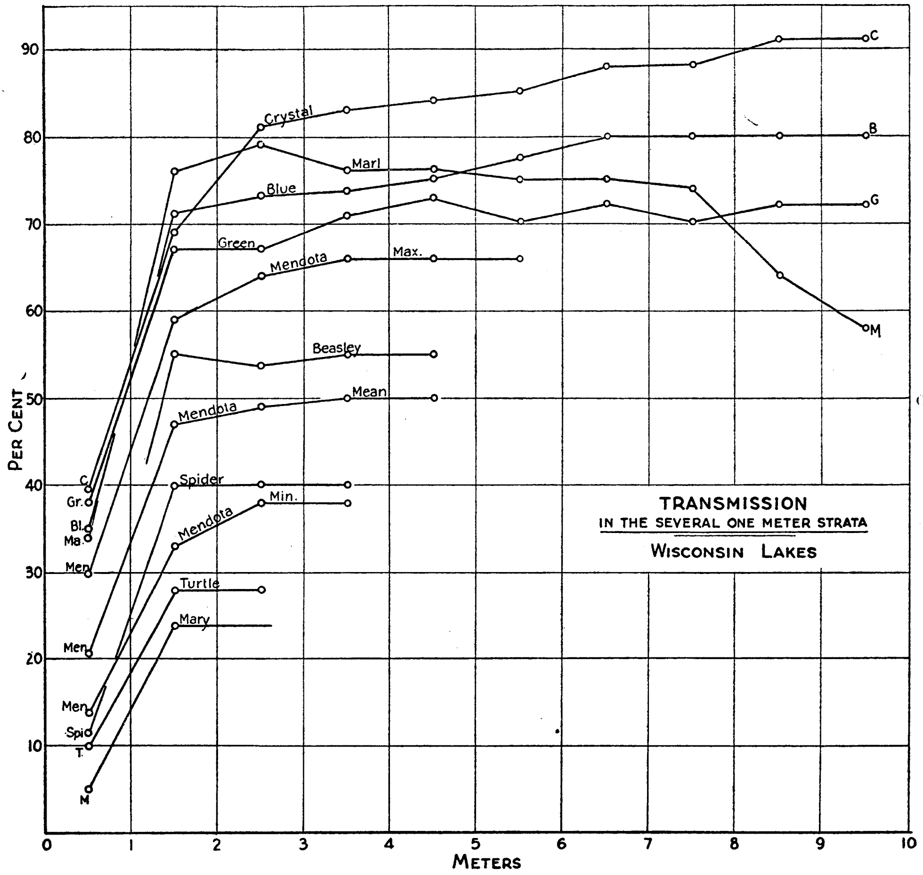


FIG. 7. Transmission curves platted to show the variations in the several one-meter strata. The per cent of transmission is platted in the middle of each stratum and the points thus indicated are connected by straight lines.

respect the record of Beasley Lake or Nagawicka Lake (table 11) with the same color; or Kawaguesaga and Oconomowoc lakes (table 11), both of which had a color of 14 with a transmission rising above 60.

TRANSMISSION IN THE UPPER METERS

Figure 8 shows on a large scale the transmission from the surface to the depth of 2 m. The curves are from lakes which represent all types from the most transparent to the most opaque in the list. The cases platted are given in the general tables and are as follows:

Adelaide, July 11, 1928
Crystal, August 10, 1928
Mary, July 11, 1928
Okauchee, August 9, 1919
Pauto, August 18, 1928
Seneca, August 1, 1918
Trcut, August 24, 1928
Turtle, August 30, 1918

All but two of these are from the northeastern group of lakes. Very few readings have been taken at the depth of 10 cm. in the southern lakes. A series from Lake Mendota was thus taken on May 29, 1928, which is recorded as the maximum series. It would almost exactly coincide with the curve from Lake Pauto. All series were taken on occasions when the surface of the lake was free from waves or even larger ripples. However, the readings at 10 cm. cannot claim the accuracy that belongs to those at 100 cm. The rate of transmission is changing rapidly at this depth since the long wave radiation is being rapidly absorbed. A difference of even a half centimeter in depth would make a decided difference in the per cent recorded; and in working over the side of a rowboat small errors in depth are sure to occur. However, the general correctness of the results is clear.

The curves platted in figure 8 are not corrected for zenith sun, but are taken from the results directly observed. The rate of transmission is changing so rapidly in the surface centimeters of the lake that it is not advisable to make such corrections without having a much larger amount of data, and indeed without data obtained with greater accuracy than is ordinarily practicable in observations made from a boat.

The rapid loss of long wave radiation in the upper 10 cm. appears in the fact that, at this depth, there remains only from 35 to 60 per cent of the radiation received by the surface. The percentage of loss falls off rapidly as depth increases, since at 25 cm. there is left from 21 to 51 per cent

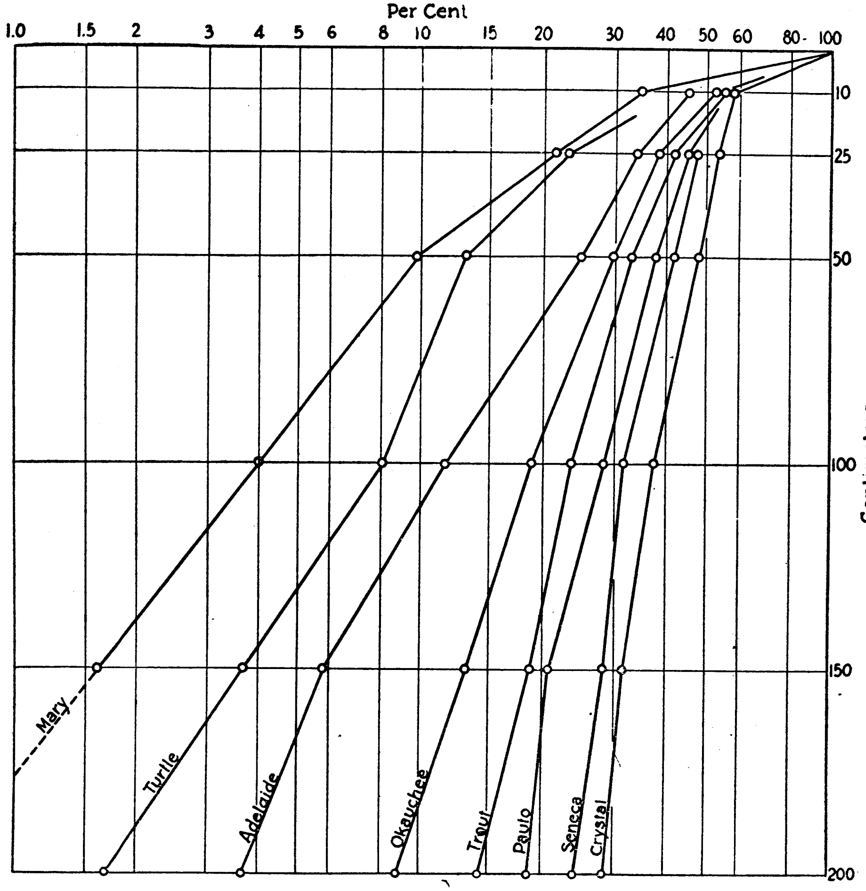


FIG. 8. Transmission in the upper two meters. In this diagram the scale of depth is ten times that of the other diagrams. The result is to bring out the small variations as well as the major changes as depth increases. Turtle Lake has an unusually irregular curve, and was selected for that reason. The other curves show the ordinary and normal variations in lakes covering the scale of transparency. The curves are platted as observed, and are not corrected for zenith sun.

of the surface radiation, or from 60 to 80 per cent of that present at 10 cm. At 50 cm. only 10 per cent of surface radiation is left in the case of Lake Mary, while in Crystal

Lake nearly 45 per cent remains. At 50 cm. in Lake Mary there has been lost about 50 per cent of the radiation present at 25 cm.; the loss between 25 cm. and 50 cm. may be less than 15 per cent in Crystal Lake.

At 100 cm. there remains in Lake Mary about 4 per cent of the radiation delivered to the surface, while in Crystal Lake about 38 per cent is present. Thus, while there is about a two-fold range in the amount of radiation present at 10 cm., the range is nearly ten-fold at one meter. In Lake Mary the 50–100 cm. stratum transmits about 40 per cent of the radiation received by its upper surface; while in Crystal Lake more than 85 per cent is thus transmitted.

In all of the lakes transmission necessarily increases with depth. In Crystal Lake the transmission of the several strata 10–25 cm., 25–50 cm., 50–100 cm. is of the same order of magnitude, i. e., about 85 per cent, in spite of the difference in thickness of the stratum: and this transmission is not far different from that of 100 cm. at depths somewhat greater. In this and in similar cases this increase is due mainly to the rapid absorption of long wave radiation by the colorless water, with a corresponding reduction of the base for comparison of the several strata. At the other extreme, the transmission in Lake Mary is practically uniform from the depth of 50 cm. and in lakes Turtle and Adelaide from the depth of 25 cm. only accidental variations of transmission appear. This situation is due to the high color of the water and the large amount of plankton found in it. The increase of transmission in Lake Mary at and below 50 cm. was due to the fact that the surface centimeters were more highly charged with dark gummy extractives from peat than were those just below. In all these cases color cut off so much of the short wave radiation that the energy spectrum quickly assumed what may be called a symmetrical form and its content thereafter fell off at a nearly uniform rate.

Transparency and Transmission

It is commonly said that there is no observable correlation between the depth at which Secchi's disc is visible and the transmission of radiation (Aufsess '03, p. 46, Oberdor-

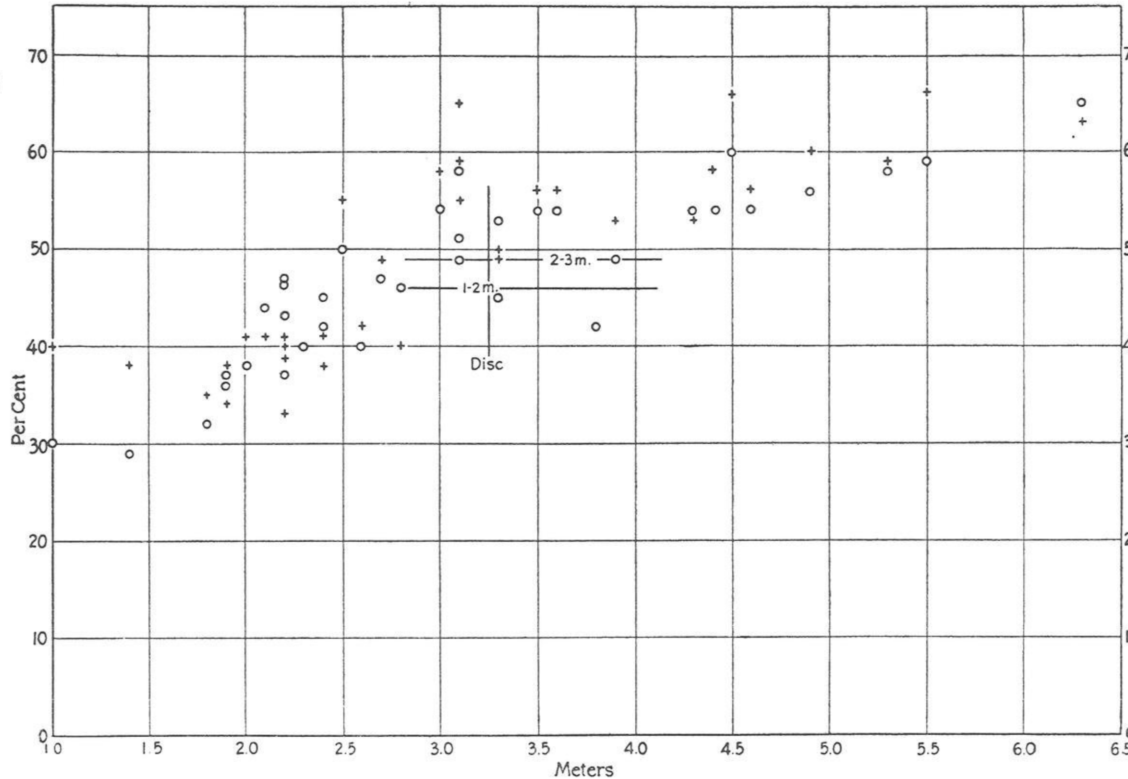


FIG. 9. Transparency and transmission in Lake Mendota. The abscissas represent the depth in meters at which Secchi's disc disappears and ordinates represent the transmission. Circles indicate transmission in the 1–2 m. stratum; crosses indicate transmission in the 2–3 m. stratum. The mean depth at which Secchi's disc disappears is marked by a vertical line at 3.2 m. The mean transmission in the 1–2 m. stratum is marked by a horizontal line at 47.2 per cent; that of the 2–3 stratum is marked at 49 per cent. For other details see text, p. 000.

fer '28a, p. 478). This statement is true in general and is indeed the only conclusion which one would reach as the result of a few observations. Stain affects transmission much more than it does transparency and where this is a dominant factor in the lake, correlation is absent or difficult to determine. Since the amount of suspended matter is one main factor in determining both transparency and transmission, there should be at least a rough correlation between the results where this factor has a large part to play.

Where numerous observations are available such a rough correlation between disc and transmission is easily found. Figure 9 shows the result for Lake Mendota of platting transmission against transparency or the depth to which Secchi's disc was visible. For every unit of depth there is a large range of transmission, provided there are enough observations. Thus, in the 1-2 m. stratum there is a range of transmission from 37 to 50 when the transparency is from 2 m. to 3 m.; the range is from 42 to 58 when the transparency is between 3 m. and 4 m. Where the transparency was 3.1 m. the transmission in three cases was 49, 51, and 58.

On the other hand, if the mean transparency and mean transmission are determined it will be found that 18 cases come below the mean of transparency and 18 at or above it. In the 1-2 m. stratum (marked with a circle in the diagram) there are 6 cases below the mean transparency and at or above the mean transmission; but of these only 2 are more than 1 per cent above the mean. Of the 18 cases above the mean transparency, 16 are also above the mean transmission. Much the same result is seen also in the cases from the 2-3 m. stratum, which are marked with a cross in the diagram.

It would be possible to draw a mean curve, representing the relation between transparency and transmission; but the number of cases is so small and the range in each rubric is so great that it is not worth while to attempt it. It is evident that transmission rises faster than transparency at first and more slowly afterwards; so that when transparency is at or near mean almost all cases of transmission are

TABLE 4. *Relation of transmission and transparency in the several lakes. Transmission in the 1-2 m. stratum only. The figures in the several columns indicate the number of cases.*

Disc, meters	Transmission, per cent													
	10–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80+	Total
1– 2	2	1	1	1		1		1			1				8
2– 3		1	1		3	2	2	5	4	2					20
3– 4				2	1	1		3	6	3	4				20
4– 5								2	5	4	1				12
5– 6									6	3	3	1			13
6– 7											1	1	1		3
7– 8												2			2
8– 9											1	2	1		4
9–10										1	1		1		3
10–11											1	1	2		4
11+												1		1	2
Total	2	2	2	3	4	4	2	11	21	13	13	8	5	1	91

above the mean. This situation means that in the higher rubrics of transparency the transmission comes to depend more and more on the effect of stain and water, while in the lower rubrics the suspended matter is a larger factor in determining the result, both for transparency and transmission.

A similar result is reached when the relation between disc and transmission is studied in the list of table 11. The results are shown in table 4.

This table, in which all lakes except Mendota are represented, shows relations of much the same order as does the large series of observations from Mendota. Low transparencies are accompanied with low transmission and high transparencies with high transmission. There is also a wide range of transmission under each rubric of transparency and a wide range of transparency under each rubric of transmission. The two cases which carry the range of transmission beyond 50 when the disc was visible between 1 and 2 m. both come from the marly lakes of Waupaca; and these lakes are exceptional in this relation (see p. 000). However, the transmission in those lakes whose visibility was 2-3 m. has also a great range and the cases are scattered along the whole distance. There is no case of a lake with transparency more than 4 m. and transmission below 50; similarly, all lakes with visibility beyond 5 m. have transmission greater than 55. No lake goes much beyond 70 unless its transparency is greater than 6 m.

In these 91 cases the transparency lies between 2 m. and 6 m. in 65 cases or 71 per cent, and the transmission lies between 50 and 69 in 58 cases or 64 per cent. The cases of relatively high transmission are dominated by the 27 series from three lakes, Trout, Green, and Crystal; so that no detailed discussion would be profitable.

It should be noted that this table deals with the 1-2 m. stratum only; if deeper strata were included the transmission would be higher, as may be seen from the tables from which these data are taken.

LAKE MENDOTA

DATA

Lake Mendota is a lake typical of southeastern Wisconsin. It lies in lat. 43.1° N.; long. 89.4° W. It is relatively shallow (25 m.), has hard water (about 40 to 55 p.p.m. of CaO and MgO), has very abundant plankton, and water which is not highly colored (6 to 10 on U. S. G. S. scale). Under these conditions transmission of radiation is low and very variable, the variations depending primarily on the amount of suspended matter in the water.

Many observations have been made in the lake at all times during the warmer season and wide extremes of transmission have been recorded; so that practically all of the other similar southeastern lakes come within their range, as do also many lakes of the same type in northeastern Wisconsin.

In table 5 are recorded 36 series of observations on Lake Mendota, taken from 1912 to 1928, mostly during the summer. Many other series are not included because they do not add to the knowledge derived from those in the table. In some of the earlier series the readings extended only to two meters. All of these are omitted, although the transmission below two meters is ordinarily much the same as that in the 1-2 m. stratum. In other cases the observations were interrupted by cloud or made irregular by streaks of haze or high cirrus. The recorded observations give both maximum and minimum cases and yield a mean which is sensibly the same as that which would result from the inclusion of all.

In many cases the observations ended at the depth of three meters. In 16 cases out of the 36 in the table they went to four meters and in 7 to five meters. The swing of the galvanometer in the deeper water is small; at three meters it was ordinarily four or five divisions of the scale; at four meters it would be about half that amount and correspondingly smaller at five meters. Under such conditions the computed transmission comes to depend on the estimate of the fraction of a division in reading the scale and is correspondingly uncertain. In general the conditions of transmission below the surface meter are nearly uniform down to the depth which we have set as the limit of our study—that at which one per cent of the incident radiation is found. This depth is well within the limits of a uniform epilimnion during the summer.

Results

The per cent of incident radiation present at the depth of one meter below the surface has been computed on the assumptions that the sun is in the zenith and that all radiation comes directly from the sun. In that case the radiation passes through one meter of water in reaching the same depth below the surface. The result is as follows:

Mean per cent, 20.7; maximum, 27.8; minimum, 13.9.

Table 5 gives no ground for inferring that the altitude of the sun affects this result, if observations are reduced to zenith sun. The two series on July 10, 1916, give substantially identical results (see p. 518 and fig. 1), and in general there is no correlation between the hour of the day and the percentage at one meter.

The minimum per cent happens to be just one-half of the maximum. It is not probable that this relation would be found if a larger series of observations were taken with special reference to it. It is not likely that much more than 28 per cent would be found at one meter, for no lake of similar type in Wisconsin has yielded a higher per cent, as may be seen from table 11. On the other hand, the water of Lake Mendota has often been more densely filled with algae than on any occasion when observations were made on radiation; and under such conditions the transmission in the surface water would be lower, as may be seen from the case of Lake Kegonsa in table 11.

Readings were taken in all cases at the depth of 50 cm., with the following result, when computed for zenith sun:

Mean per cent, 33.1; maximum, 41.0; minimum, 28.0.

In 18 cases readings were taken at the depth of 25 cm. below the surface. The mean result was to give at that depth 1.33 times the per cent at 50 cm. This would give a mean of 44 per cent of incident radiation present at 25 cm. depth. These results have been used in platting the mean transmission curve of radiation (fig. 10).

Transmission below the depth of one meter

The transmission of radiation through the successive one meter strata of water below the surface is as variable as is the per cent present of the depth of one meter. The results are:

1-2 m. stratum

Mean per cent, 47.3; maximum, 65; minimum, 29.

2-3 m. stratum

Mean per cent, 48.7; maximum, 66; minimum, 34.

Thus the mean transmission increases slightly with depth in the upper meters, as would be expected. If the transmission curve is platted on a large vertical scale, this increase is apparent. But when platted on the scale used in figures 3-6, the fact hardly appears. It is also true, as table

TABLE 5. *Transmission of solar radiation in the surface water of Lake Mendota.*

No.	Date		Hour		Trans. m'trs	Cosine, cm.	Cal. cm² min.	Per cent at 1 m.	Transmission 1-2 m.	2-3 m.	3-4 m.
1	July 17	1912	11:16	11:57	1.9	96	1.34	18.1	37	38	------
2	Aug. 27	1912	11:31	12:35	1.8	90	1.26	17.4	32	35	------
3	May 7	1913	11:05	11:40	2.1	94	1.28	21.7	44	41	42
4	May 10	1913	11:20	11:54	2.4	94	1.40	19.3	45	41	42
5	May 16	1913	10:40	11:00	2.8	93	1.29	22.2	46	40	------
6	May 27	1913	10:22	11:18	3.3	95	1.32	23.3	45	49	49
7	June 13	1913	11:37	12:06	2.3	96	1.38	17.7	40	40	40
8	Aug. 8	1913	10:20	10:50	2.2	94	0.99	19.7	37	33	------
9	July 21	1915	10:54	11:23	2.2	94	1.12	20.4	43	41	------
10	Aug. 13	1915	11:52	12:13	4.3	93	1.23	25.5	54	53	------
11	June 27	1916	12:05	12:45	1.9	95	1.29	17.1	36	34	------
12	July 5	1916	4:02	4:19	2.0	78	0.61	20.4	38	41	------
13	July 7	1916	4:11	4:43	3.3	77	0.56	24.0	53	50	------
14	July 10	1916	12:19	12:37	2.2	96	1.11	16.7	47	47	------
15	July 10	1916	4:20	4:36	2.2	77	0.54	17.0	47	47	------
16	July 24	1916	12:06	12:21	2.4	76	0.71	18.0	42	38	------
17	July 26	1916	4:35	4:48	3.8	95	1.05	18.1	42	44	------
18	Aug. 30	1916	11:40	12:08	3.0	90	1.10	21.9	54	58	------
19	Oct. 11	1916	11:24	11:42	3.9	82	0.93	20.7	49	53	------
20	Nov. 4	1916	12:04	12:17	3.6	76	0.80	22.8	54	56	------
21	June 10	1917	11:30	12:00	4.5	96	1.18	22.7	60	66	------
22	Aug. 18	1917	11:43	12:00	3.5	93	1.03	21.0	54	56	------
23	Sept. 22	1917	10:17	10:55	4.6	84	1.51	23.3	54	56	------
24	Nov. 11	1917	11:36	11:58	4.4	76	0.92	20.9	54	58	55
25	Nov. 16	1917	11:33	12:00	4.9	76	0.93	24.7	56	60	59
26	Nov. 20	1917	11:43	12:02	5.3	74	0.83	24.4	58	59	57
27	Aug. 13	1918	11:55	12:20	3.1	93	0.90	20.5	58	55	59
28	May 30	1919	11:30	11:53	6.3	96	0.87	24.0	65	63	------
29	Sept. 1	1920	11:50	12:07	3.1	90	1.06	18.6	49	59	56
30	Sept. 7	1920	12:00	1:00	3.1	89	1.17	26.9	51	65	63
31	May 17	1926	10:32	10:58	1.0	93	1.23	14.0	30	40	40
32	May 20	1926	10:45	11:10	1.4	93	1.26	13.9	29	38	35
33	May 27	1926	10:40	10:55	2.5	93	1.33	22.2	50	55	62
34	May 1	1928	10:12	10:41	2.7	91	1.21	22.1	47	49	50
35	April 20	1928	10:00	10:17	2.6	87	0.99	16.3	40	42	42
36	May 29	1928	9:23	9:45	5.5	90	1.13	27.8	59	66	66

5 shows, that an increase below 2 m. is by no means always present, and figure 10 shows the reason. The transmission curve of the filtered water is shown in comparison with those of the lake. At 3 m., for instance, there would be about 20 per cent of incident radiation present in filtered water. In the lake the maximum found at 3 m. is 11 per cent, or about half as much, and from this it ranges downward to 1.8 per cent, or about 9 per cent of that present in the filtered water. At 5 m. the filtered water would have reduced radiation by about 8 per cent, leaving 12 per cent; while in the lake there remain from 5 to 0.25 per cent. Thus suspended matter decreases transmission by a very large and a very variable amount and may quite obscure the more modest effects of water and stain at depths below one or two meters. The occluding effect of suspended matter depends mainly on its relative abundance, which is very variable. Hence the transmission in deeper strata may be greater or smaller or remain about the same, according to the balance of these variable factors. In general, there is a slight increase.

In 16 cases the radiation was followed through the 3–4 m. stratum and the mean result was a transmission of exactly 50 per cent. The few cases where the transmission through the 4-5 m. stratum was measured gave no reason for inferring any further increase. In computing the average progress of radiation through the lake a transmission of 50 per cent per meter has been assumed for all depths below three meters. At this rate the radiation would be reduced to one per cent of its surface value at the depth of 5.3 m. below the surface.

The depth at which one per cent of incident radiation is found is computed for the single observations on the assumption that the transmission found in the lowest meter observed is continued in the underlying meters. The maximum depth thus found is 8.8 m., May 29, 1928. The minimum depth is 3.5 m., May 20, 1926. This difference was due to a marked difference in the plankton, which also showed itself in the transparency as measured by Secchi's disc. In the first case readings extended to 6 m. and in the second to 4 m. The series of 1928 was made by the aid of the new and sensitive millivoltmeter.

TABLE 6. *Mean effect of insolation, computed for zenith sun.*

Depth, meters	Per cent present	Transmission Depth	Transmission Per cent
1	20.70	1–2 m.	47
2	9.73	2–3 m.	49
3	4.77	3–4 m.	50
4	2.38	4–5 m.	50
5	1.19	5–6 m.	50
6	0.60		

No considerable error would be made in asserting as a general statement, that with zenith sun 20 per cent of incident radiation is present at one meter depth in Lake Mendota; and that the average transmission per meter below that depth is 50 per cent.

The observations recorded in table 5 are reduced to zenith sun and are therefore maximum. They do not represent the average per cent of radiation which is found at one meter during a day or during the season. The average path of radiation direct from the sun in reaching the depth of one meter is longer than that assumed, and the presence of much diffuse radiation from sky and cloud adds to the length of the average path. The amount of incident radiation which is reflected increases as the angle of incidence decreases and thus the amount that enters the water is diminished.

Mean path of radiation; "mean sun"

The mean path of total radiation, including both direct and indirect, which enters the lake has been computed with allowance for reflection, as stated on p. 576. The lake reaches the temperature of 4° C. about April 15 and both warming of the water and the growth of plants from the bottom are substantially completed by August 15. This may be called the "warming period" of the lake. The mean path of radiation in reaching the depth of 100 cm. below the surface during this period is computed as 116 cm. The radiation at 1 m. below the surface has therefore suffered an average loss equivalent to that from 1.16 m. with zenith sun. The transmission curve for zenith sun is marked at depths of 1.16 m., 2.32 m., etc. The figures thus obtained show the average situation during the warming season, of course on the assumption that the transmission remains the same.

Applying this method to the curve of mean transmission with zenith sun gives the following result:

TABLE 7. *Mean results during warming period.*

Depth, meters	Per cent present	Transmission Depth	Transmission Per cent
1	18.30	1–2 m.	43
2	7.80	2–3 m.	45
3	3.45	3–4 m.	45
4	1.55	4–5 m.	45
5	0.70		

The base for computing per cent in column 2 is the total radiation in air, not that which enters the water.

During the period April 15–August 15 the lake receives about 60,000 cal. cm.², and of this amount about 4,620 cal. are reflected from the surface. The following table shows the quantity of radiation delivered to different depths in the lake, on the above assumptions.

TABLE 8. *Calories per square centimeter delivered during warming period. Computed for "mean sun," April 15–August 15.*

Depth, meters	Cal.	Depth, meters	Cal.
1	10,980	0–1 m.	44,400
2	4,650	1–2 m.	6,300
3	2,070	2–3 m.	2,610
4	930	3–4 m.	1,140
5	420	4–5 m.	510
		Below 5 m.	420

Most of the enormous quantity of heat which enters the surface meter is used in evaporation, is rapidly returned to the air, or is distributed by wind to deeper strata. The longer wave lengths penetrate only a very short distance. The 1–2 m. stratum gets from the sun nearly three times as much heat as is retained; its mean maximum temperature may be placed at about 24°, requiring 2,000 cal. cm.² to warm it from 4° to this point. The 2–3 m. stratum,

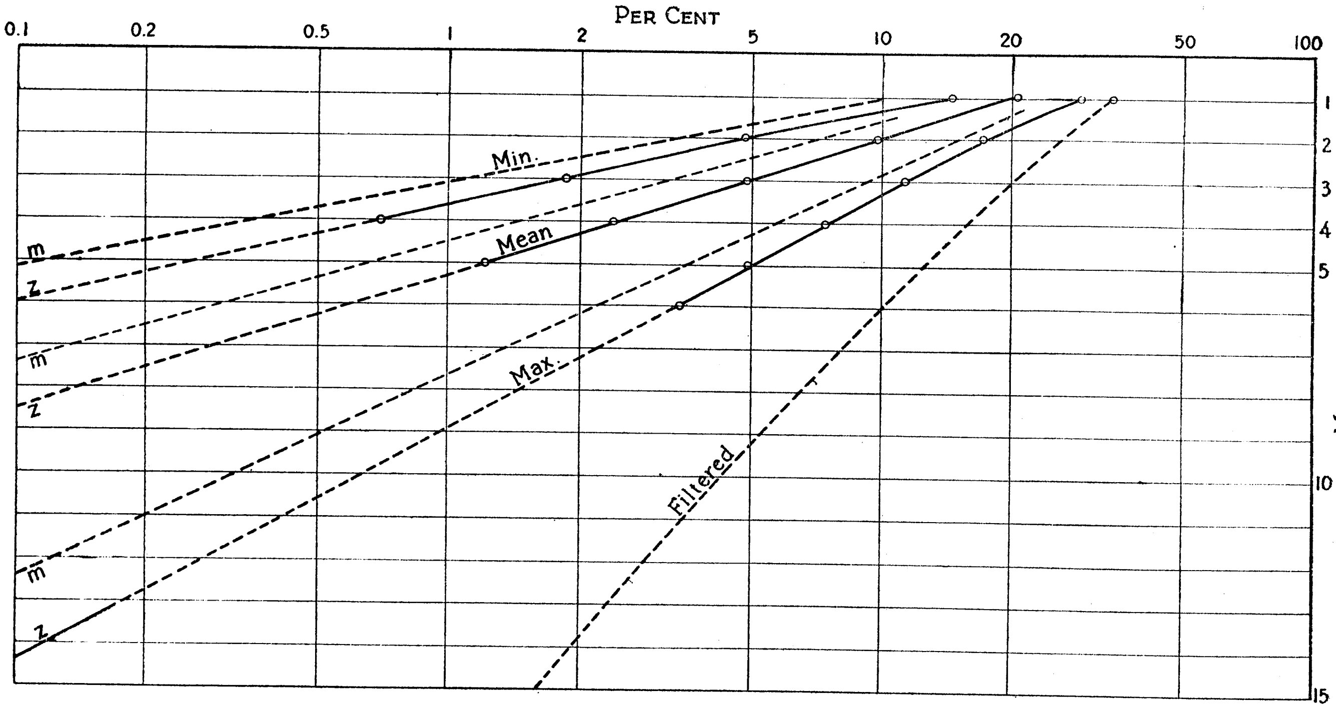


FIG. 10. Transmission curves for Lake Mendota, showing the curves for filtered water, and mean, maximum, and minimum for the lake, extended to 0.1 per cent. The last three are given in two forms, that for zenith sun and that for mean sun. See text p. 548.

which has the same average temperature, gets from the sun directly only a little more than it retains; the meters below get from insolation much less than they receive altogether, and below 5 m. the effect of direct insolation is almost negligible so far as the warming of the lake is concerned.

The region of the solar spectrum between 0.360μ and 0.762μ contains about one-half of the total energy present in the whole spectrum, and practically all of the energy delivered by insolation to depths of one meter or more belongs to this region. If, therefore, the percentages of radiation given in tables 5 and 11 are doubled they will yield a fair estimate of the radiation present as light at these depths. This is energy measured in calories per square centimeter of area.

Rickett ('22, p. 500) found that higher plants grow from the bottom in Lake Mendota to a maximum depth of about 6 m. At this depth there should be present an average amount of about 0.6 per cent of the energy received by the surface in the form of radiation within the visible spectrum as defined above. When the sun is high in the sky this per cent might be doubled or trebled, and at maximum transparency and high sun more than 4 per cent might be present at this depth. The region of the spectrum to which the water of Lake Mendota is most transparent has its center about 0.550μ and a much larger percentage of a spectral band in this region would reach the depth named. This band lies in the region of green and yellow light.

Figure 10 shows the transmission curves for Lake Mendota, the minimum case, the mean of 36 series, and the maximum; they are given for zenith sun and also for mean sun. There is also platted on the same diagram the transmission curve of the filtered water of the lake; this curve is a mean from five series. The minimum curve was read to the depth of four meters; the maximum to six meters; all are adjusted for zenith sun.

All curves are extended until they intersect the line representing 0.1 per cent of the radiation delivered to the surface; or until they intersect the line representing 15 m. The depth at which one per cent is reached is: minimum, 3.6 m.; mean, 5.2 m.; maximum, 7.9 m.; filtered water, 16.0 m. Since the color of the water does not vary greatly at different times we may conclude that the difference in transmission is largely due to the varying amount of suspended matter in the water.

The difference between the several curves increases rapidly as they are carried down. The following table shows the situation.

TABLE 9. *Lake Mendota. Per cent of radiation present at various depths.*

	5 meters	10 meters
Transmission, Minimum,	0.25	0.0017
Transmission, Mean	1.20	0.035
Transmission, Maximum	4.90	0.64
Transmission, Filtered Water	11.0	3.70

Thus at 5 m. the maximum amount of radiation is about 20 times as great as the minimum; at 10 m. the mean is nearly 20 times the minimum and the maximum about 20 times the mean; so that the maximum is nearly 400 times the minimum, or the difference is 20 times as great as at 5 m. Similar relations can be traced if the changes in each curve are followed from 5 m. to 10 m.

THE SOUTHEASTERN LAKES

DATA

Tables 10 and 11 contain the data from the lakes both of southeastern and northeastern Wisconsin. They also contain data from four lakes outside of Wisconsin.

In table 10 are given records from the lakes in which observation extended to the depth of 9 or 10 m. These include 9 of the more transparent lakes from all regions. The per cent present at each depth is recorded and also the transmission through the several one-meter strata. Table 11 gives in summary form the records from all lakes to the depth of 5 m., if observation went so far. The transmission curves from many of these lakes are shown in figures 3–6.

RESULTS

The list includes 26 lakes from the southeastern district, besides Lake Mendota, with 45 series of observations. In general, their records agree with those from Lake Mendota. This would be expected, since the general character of the lakes is similar. They are glacial lakes situated in a region of drift that contains much calcium and magnesium. The water of the lakes, therefore, contains much of the salts of these elements and the amount and nature of the plankton are partly determined by this fact. The amount of stain in the several waters does not differ greatly. It is not surprising that the figures given in table 11 should show that in many of the lakes the amount of radiation found at a depth of one meter and the transmission through successive meters lie within the limits observed in Lake Mendota.

In each case a long series of observations would probably disclose a different mean result from that found in Lake Mendota. Shallow and active lakes like Kegonsa will be found to have much more plankton than Mendota and the transmission of radiation will suffer accordingly. Deep lakes like Green and Geneva have much less plankton and the transmission is correspondingly higher. Lakes like Okauchee, Nagawicka, and North are affected by the large amount of material brought in by affluents from a wide area. Pine, Elkhart, and Mouse are lakes fed by springs and are without affluents or adjacent marsh; they are correspondingly transparent.

In spite of these differences of detail the resemblances between these lakes are far more noteworthy than the differences. But there are two obvious exceptions to these statements—the marl lakes of the Waupaca group and Devils Lake. In the marl lakes the presence of this substance is decisive in determining the character of the lake. The dissolved salts of the water are not greatly different from those in other lakes (Birge and Juday '11, pp. 170–171), but the presence of numerous particles of marl in the water affects its color and the plankton which it carries. These lakes have a low transparency as measured by Secchi's disc, owing to the lack of contrast between disc and background; but they have a high transmission of radiation and a relatively large per cent is present at the depth of one meter. The location and surroundings of Devils Lake give it a character widely different from any other southeastern lake. It is really an outlying member of the northeastern group of soft water lakes—a group which lies 150 miles (250 km.) to the north.

The lakes of southeastern Wisconsin are members of three groups besides five single lakes. They may be arranged as follows:

1. Three of the lakes of the Four Lake group—Mendota, Monona, and Kegonsa. These are all connected by the Yahara River.
2. Eight lakes from the Oconomowoc group—Garvin, Mouse, Nagawicka, North, Pine, Oconomowoc, Okauchee, Upper Nemahbin. This group lies close to lat. 43.1° N., long. 88.2°–88.5° W.
3. Eleven lakes from the Waupaca group—Beasley, Columbian, Knights, Long, Marl, McCrossen, Otter, Pope, Rainbow, Round, Taylor.
4. Five single lakes—Crystal and Elkhart, Devils, Geneva, Green.

All of these lakes are fully described in Juday, '14 and only those matters will be mentioned here which are essential to the understanding of the table.

1. Monona and Kegonsa lakes are less deep than Mendota, and they have a larger amount of plankton for each unit of volume. The amount beneath each unit of surface in these lakes is much the same and since the depth is less the number of organisms in a cubic meter is greater. The result is to cause a greater obstruction to the passage of light. This does not appear in the series from Monona which happened to come on a day when the plankton was unusually low; but it is very conspicuous in that from Lake Kegonsa. The color of the water is much the same as that of Mendota and has a similar effect on the light; and the transmission will be greater or less according to the abundance of the plankton.

2. The several lakes of the Oconomowoc district fall into two groups. North, Okauchee, and Oconomowoc lakes are strung along on the Oconomowoc River, and Nagawicka and Nemahbin lakes are on the Bark River. In both cases the situation is like that of the Four Lakes. Pine Lake and Mouse Lake are spring-fed, with little or no marsh adjacent

and without affluent or effluent. They show a corresponding transparency and transmission, but both are within the limits of Lake Mendota. Garvin Lake has a similar situation; but it is so small that its character is determined by the wash from the adjacent slopes.

It will be noted that the transmission in the 1–2 m. stratum of North Lake on August 9 differs greatly from that of the 2–3 m. stratum. The visit to the lake on August 19 was was made to ascertain whether the peculiar situation on the 9th was due to temporary or permanent causes. It appeared that the former was the case and probably the low transmission on the 9th was due to an unusual concentration of plankton.

3. The Waupaca group of small, deep lakelets offers very interesting differences. The Waupaca Chain o' Lakes consists of 12 lakes or lakelets and extends about 5 km. from Otter Lake on the northeast to Marl Lake on the southwest. The lakes are therefore small, ranging from Beasley with an area of 5.4 ha. to Rainbow with 55.7 ha. Their depth is considerable, ranging from 12 m. to 29 m. There are substantially no affluents and all lakes discharge through Long Lake. Six lakelets lie to the east and five to the west of the outlet. They are in lat. 44.4° N.; long. 89.2° W.

There are two widely different types of lake—the ordinary type and marl lakes. Among the lakes examined, Rainbow, McCrossen, Round and Columbian (naming them in order) are marl lakes. At the extreme end of the series Marl Lake has a like character. They have large marl deposits on the bottom and many fine particles of marl are suspended in the water. The last matter is especially evident in summer when navigation on the lakes is active. The water has a bluish-green color when viewed in the lake and is nearly colorless when filtered. The transparency of the lakes, as measured by Secchi's disc, is low and the transmission of radiation is high. The lake bottoms in shallow water support only a scanty plant life.

The lakes of the other type are Beasley, Knights, Long, Otter, Pope. In these there are no marl springs; the water is obviously stained; there is an abundant growth of plankton and of plants on the bottom; the transparency is usually greater than that of the marl lakes, but the transmission of radiation is less. Taylor Lake seems to be somewhat intermediate in character, though nearer to the marl lakes.

In this group was found the smallest transmission among the southeastern lakes—Pope Lake, 18 per cent; also the highest transmission—Marl Lake, 80 per cent. The marl lakes had ordinarily a transmission above 60 per cent, though with exceptions; lakes of the other type rarely exceeded 60 and often fell below that number.

The three series recorded for Marl Lake offer an instructive case of the effect of suspended matter on transmission. There is no reason to suppose that the absorption of radiation by the water of the lake differed notably on the three occasions. There is no adjacent marsh and there is very little opportunity for drainage water to enter from the surrounding country. The difference in transmission was due to suspended matter, chiefly particles of marl. There is a rough correlation between transparency and transmission in these cases. One of them furnishes the only case from the southeastern lakes where the transmission exceeds 80.

4. Among the single lakes, Crystal Lake must not be confused with its namesake in the north. It is a very different lake in all respects. It is situated not far from Elkhart Lake and it presents the ordinary type of a rather shallow southeastern lake. Each of the other four lakes in the class has points of special interest.

Elkhart Lake (lat. 43.8° N.; long. 88.0° W.) is a small deep lake (121 ha., 34.5 m.) lying in a hollow of the Kettle Moraine. It is exceeded in depth only by Geneva and Green lakes in the southeastern group; and Trout Lake in the north is perhaps a meter or two deeper. It has no affluent and little or no adjacent marsh so that its water is clear. In accordance with this situation and with the depth of the lake, it has a high transmission, showing over 30 per cent of incident radiation at one meter, and a transmission reaching 75 per cent below that depth.

Geneva Lake (lat. 42.6° N.; long. 88.5° W.—2210 ha., 43.3 m.) in the extreme southeast of the state, lies in an old drainage valley which has been blocked by glacial action. As would be expected from its depth the transmission is relatively large. On both occasions when the lake was visited the transparency was greater than usual and it is probable that the transmission was also higher than a larger number of series would show.

Green Lake (lat. 43.8° N.; long. 88.6° W.—2972 ha., 68 m.) also lies in a preglacial valley. It is the deepest inland lake in Wisconsin and apparently the deepest inland lake between the Finger lakes of New York and the lakes of the Rocky Mountain region. It is also the largest lake of Wisconsin except the very shallow Lake Winnebago (558 sq. km., 6.4 m.). It is the only lake in Wisconsin that fully complies with the character of an oligotrophic lake as defined by European limnologists. Much study has been given to it by the Survey, since it presents characteristics widely different from Lake Mendota and the other southeastern lakes. The relation to radiation is recorded in ten series in six different years from 1912 to 1923. There are other series which are omitted as either too short or otherwise imperfect. Their results are in general agreement with those which are in the list. All but one of these series extended to the depth of 8–10 m. The shore of the lake is so steep in places that a depth considerably exceeding 10 m. can be found within less than 100 m. of the shore. In general the readings were limited to the epilimnion, which ends at eight or ten meters in July and August. It is often impossible to get satisfactory readings of the pyrlimnometer at the level of most rapid transition to the thermocline, as the small and rapid oscillations of temperature in the water obscure the effect of the sun.

The average amount found at one meter was 27.3 per cent of the incident radiation, with a maximum of 30.6 and a minimum of 23.3 per cent. The average transmission in the 1–2 m. stratum was 64, rising to 69 in the 3–4 m. stratum and remaining close to that figure below, though rising beyond 70 at 9 or 10 m. In all of these particulars there is a close resemblance between Green Lake and Trout Lake in the northeastern group of lakes.

Devils Lake (lat. 43.3° N.; long. 89.7° W., 146 ha., 12 m.) differs widely from all the other southeastern lakes. It lies in the gorge where the preglacial valley of the Wisconsin River passed through the quartzites of the Baraboo

Range. This valley was deeply filled with drift and on top of this filling the lake lies between two sandy ridges. On the east and west sides the lake is bounded by the talus of the quartzite cliffs. The water of the lake is soft, containing 5–7 p.p.m. of fixed carbon dioxid, or less than one-tenth as much as the average southeastern lake. The plankton is small in quantity and the lake is the only one in southern Wisconsin in which Holopedium is regularly found. There are no affluents and very little adjacent marsh. The water has little color and the lake is unusually transparent.

The average transmission of the lake exceeds that of any other southeastern lake and approaches that of the clearest lakes in the northeastern district. Over 30 per cent of incident radiation may be found at one meter and the transmission may rise to 80. This was also reached by Marl Lake, but only as an exceptional case, while there is no reason to doubt that it may often be attained in Devils Lake.

Green, Geneva, and Elkhart lakes belong to a group of moderately transparent lakes, which also includes Trout Lake from the northern district. These have little plankton, low color, and a transmission which regularly exceeds the maximum for Lake Mendota. So far as known, the variation in transmission (see fig. 6) is small, as would be expected from the small amount of plankton. Devils Lake forms a transition to the extremely transparent lakes of the northeastern district.

THE NORTHEASTERN LAKES

There are 25 lakes listed from the district in Northeastern Wisconsin, with 47 series of observations; as compared with 26 lakes (besides Lake Mendota) with 45 series from the Southeastern groups of lakes. This group of lakes lies close to lat. 46° N. and between 89° and 90° W. long.

The lakes of the northern group are much more varied and interesting than those from the south. The difference between the transmission of radiation in the southern lakes is largely a matter of the quantity of plankton; stain is in general a subordinate factor. The marl lakes, indeed, offer an interesting problem; having very clear water, made more or less milky by mechanical mixture of marl particles.

But these are only a few lakelets and the problem is largely a mechanical one.

No lake in the southern group has a color that exceeds 14 and none would be wholly devoid of color. In general, the stain ranges about 6 or 8. Among the northern lakes there are six whose stain exceeds 20, one of them going to 118, and four others have a color between 14 and 20. There are four lakes whose stain is regularly too small to measure and is recorded as zero. One of these, Crystal Lake, is definitely a "blue" lake, since Secchi's disc or other white objects appear distinctly blue when viewed through a few meters of its water. No other lake has been found which is so definitely blue, though several others, not in the present list, approach it. Thus both the presence and the absence of stain produce effects in the northern lakes on a scale which is quite absent from those in the south.

The northern lakes have soft water; the fixed carbon dioxid does not exceed 35 p.p.m., while in the southern lakes it ranges from 65 to 100 p.p.m., and may go beyond the larger figure.

Among the southern lakes only one had less than 15 per cent of incident radiation present at one meter; and this case (Kegonsa) was obviously due to growths of algae near the surface. Among the northern lakes there were 11 cases of a very low per cent of radiation at one meter, from 8 different lakes. Only two southern lakes (Marl and Elkhart) exceeded 31 per cent at this level, and two others had percentages between 30 and 31. One northern lake (Crystal) exceeded 35 per cent, one other (Weber) nearly reached that number, three others (Clear, Pauto, Trout) were above 31, and one (Clear Crooked) was above 30. All grades may be found connecting these extremes.

Thus the northeastern lake district contains lakes which may furnish typical examples of every type of factor affecting transmission of radiation. These are present in considerable numbers for every type and they show every grade within the type. The few lakes reported probably offer cases close to the limits of transparency for inland lakes. There are lakes much more deeply stained than any in the list; and further study will yield a much more complete series and one in which the various factors may be assigned more definite values.

The most deeply stained waters are those of Mary and Turtle lakes. Lake Mary (1.1 ha., 22 m.) is a small, deep, moraine lakelet; it normally overflows into Lake Adelaide, but in 1928 there was no overflow and the upper meter or two of water was not only deeply stained but also contained much gummy extractive from peat. Turtle Lake lies in the course of a small stream issuing from marshes; it has much plankton as well as stain. Dead Pike Lake has much stain, but little organic plankton. Lake Adelaide is high in both; and both lakes are relatively deep. Allequash and Wolf lakes are shallow and weedy and have much suspended vegetable debris. In all of these lakes the transmission is in general below 40.

There follows a group of lakes with colors ranging from 12 to 18, including Fishtrap, High, Kawaguesaga, and Lost Canoe lakes. These have also much plankton, which has much influence on transmission. This is usually below 50 and often below 40. When the plankton is low it may exceed 60, as in Kawaguesaga Lake.

The lakes with low stain—5 to 8—have a transmission which is rarely below 50, ordinarily exceeds 60 and may touch 70 (Trout Lake), or even decidedly exceed 70 (Blue Lake). It should be said that readings of color below 8 have to be estimated and may easily be lower than stated.

In the lakes which are regularly recorded as having no stain the transmission depends on the amount of plankton and the selective effect of water. The quantity of plankton is usually small; if it were large the color of the water would be affected. In these lakes the transmission does not fall below 60 in any recorded case; it ordinarily exceeds 70; it may rise above 80 and even touch 90 (Crystal Lake).

The observations on the Northeastern lakes for 1926 and 1927 are also given in the table found in Birge and Juday, '29, p. 69 (p. 8 of separate). In a few cases the figures there given differ slightly from those reported in the present paper. These variations are due to revision and recomputation and are without general significance. The series given in table 10 for Crystal Lake, July 6, 1926, is not mentioned in the earlier paper, either in the table or the discussion. This was the only case in which transmissions approaching or exceeding 90 had been found and we were unwilling to accept them. In 1928 another series was taken with transmissions essentially similar, and consequently both are now included.

When the transmission thus increases in the deeper water the question naturally arises whether this may not be due to the removal of the shadow of the boat. Oberdorfer attributes a very considerable effect to this shadow ('28, p. 150). We are not prepared to discuss the question at present, though we have given it some attention. Examination of table 10 will show cases where such an effect would be suspected and other similar cases where it is obviously absent. The effect would not be great if, as in our work, all observations are made in bright sunhine. The matter is also complicated by the fact that transmission must tend to rise in the deeper strata, as the longer wave-lengths of the spectrum are absorbed. The effect of possible reflection from the side of the boat on the reading at one meter must also be considered. This effect must be present to some extent in readings taken as ours were, and it will vary with the color of the boat.

Other Lakes

The transmission of radiation has been measured in four lakes outside of Wisconsin; in Canandaigua, Cayuga, and Seneca lakes in New York; and in West Okoboji Lake, Iowa. The last named is a lake much like those of southeastern Wisconsin; having hard water, abundant plankton, and correspondingly low transmission. The New York lakes are large, deep lakes, whose water has little stain and also little plankton. They are lakes of the same type as Green Lake, Wisconsin, but though they are much larger and deeper, their transmission is not higher than that of Green Lake. These three lakes may be taken as showing the usual situation in lakes belonging to the type called oligotrophic. Trout Lake in northeastern Wisconsin belongs to the same type, so far as plankton, stain, and transmission are concerned. In all there may be expected as much as 30 per cent of incident radiation at one meter, or perhaps somewhat more, and a transmission rising to 70 or above, but not reaching 80.

TABLE 10. *Records of the more transparent lakes, in which observations extended to 9 m. or more. Columns 0 to 10 give the per cent in air and at indicated depths with zenith sun; columns 1–2 to 9–10 give the transmission by meters. These records are repeated in table 10 to the depth of 5 m. and other data are also given there.*

Lake	Date	0	1	2	3	4	5	6	7	8	9	10	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10
Blue	Sept. 4, 1918	100	29.8	21.4	15.7	11.7	8.8	6.9	5.5	4.4	3.5	2.6	72	73	74	75	78	80	79	79	75
Crystal	July 6, 1926	100	39.7	28.5	23.0	19.2	16.2	13.8	12.3	10.6	9.6	8.7	74	81	53	84	85	89	86	90	91
	July 22, 1926	100	35.3	27.7	22.2	17.8	14.6	12.4	10.6	8.4	6.7	----	78	80	80	82	84	85	79	80	----
	Aug. 17, 1926	100	35.4	26.4	21.3	16.7	13.3	10.7	9.2	7.6	6.3	5.2	75	81	78	80	81	85	83	84	83
	June 26, 1928	100	37.5	30.2	23.3	18.8	14.5	11.7	9.8	8.6	7.8	----	81	77	81	77	80	83	88	90	----
	Aug. 10, 1928	100	38.6	29.8	22.5	18.0	15.0	12.5	10.8	8.3	6.3	----	78	77	74	77	78	84	87	80	----
	Aug. 21, 1928	100	39.0	30.6	23.6	17.7	13.7	10.7	9.0	7.9	6.3	5.0	78	77	74	77	78	84	87	80	80
	Mean	100	37.6	28.9	22.6	18.0	14.6	12.0	10.3	8.6	7.2	5.9	77	79	80	81	82	86	83	84	82
Devils	Aug. 26, 1919	100	29.5	19.7	13.8	9.9	7.5	5.9	4.6	3.7	3.0	2.4	67	70	72	76	80	79	80	80	80
	June 3, 1926	100	30.6	19.7	13.7	10.3	7.4	5.4	4.0	3.0	2.1	1.5	64	69	65	72	74	73	75	69	72
Elkhart	Aug. 26, 1918	100	33.6	21.6	15.8	11.7	8.7	6.3	4.6	3.5	2.4	1.6	66	71	74	75	75	71	72	76	70
Geneva	June 28, 1919	100	30.3	20.5	14.3	10.2	7.4	5.4	4.0	2.9	2.2	1.6	68	70	71	72	73	74	73	74	74
Green	Aug. 20, 1918	100	23.3	15.8	11.0	7.4	4.8	3.2	2.1	1.4	1.0	----	68	70	69	65	65	63	67	70	----
	Aug. 14, 1919	100	28.5	19.0	13.2	9.4	6.9	5.2	3.9	2.9	2.1	1.6	67	69	71	73	74	75	77	73	73
	Aug. 21, 1921	100	26.6	17.3	11.3	8.1	5.7	4.1	2.9	2.1	1.5	1.0	65	65	70	71	72	71	74	72	70
	Aug. 23, 1921	100	27.0	16.0	10.7	7.3	5.0	3.4	2.3	1.6	1.2	0.7	60	67	68	68	69	68	71	72	60
	Aug. 24, 1921	100	29.6	18.8	12.3	8.1	5.4	3.7	2.5	1.6	1.0	0.7	64	66	66	66	69	68	65	62	68
	Aug. 9, 1922	100	25.0	14.5	9.2	6.1	4.4	3.1	1.8	1.2	1.0	----	59	64	66	73	70	60	69	83	----
	Aug. 5, 1923	100	30.6	20.5	13.7	9.8	7.2	5.0	3.6	2.6	1.8	1.3	67	67	70	74	74	75	76	74	72
	Aug. 19, 1923	100	28.0	17.0	11.2	7.5	5.0	3.5	2.4	1.7	1.2	0.8	61	66	67	68	69	69	69	74	68
	Mean	100	27.3	17.4	11.6	8.0	5.6	3.9	2.7	1.9	1.4	1.0	64	67	69	70	70	69	70	72	72
Marl	Aug. 25, 1918	100	34.3	26.0	20.5	15.5	11.8	8.9	6.7	5.0	3.2	1.8	76	79	76	76	75	75	74	64	58
Seneca, N. Y.	Aug. 1, 1918	100	32.1	22.5	16.4	11.5	8.1	5.7	4.1	2.7	2.0	1.5	70	72	71	70	70	71	70	72	77
Trout	Sept. 1, 1918	100	27.5	17.0	11.3	7.4	4.9	3.3	2.2	1.6	1.1	----	62	66	65	66	68	68	70	70	----
	June 29, 1926	100	26.5	16.7	11.2	7.7	5.4	3.8	2.8	2.0	1.4	1.0	63	67	69	71	70	72	71	72	68

TABLE 11. *Records of all lakes except Mendota and extending to the depth of 5 m. The color is given on the platinum-cobalt scale of the United States Geological Survey. By "cosine r" is meant the cosine of the angle of refraction corresponding to the altitude of the sun at the time of observation. It furnishes the distance by which the observed transmission curve is corrected for zenith sun (see p. 518). Calories, centimeter square, minute, are stated for a horizontal surface at the time of observation; they are not adjusted for zenith sun. The column headed "1% at meter" gives the depth at which radiation would be reduced to one per cent of that delivered to the surface, assuming zenith sun and direct radiation (see p. 576). This depth with mean sun would be 86 per cent of the depth stated. Lakes numbered from 1 to 26 belong to Southeastern Wisconsin; numbers 27–51 are in the Northeastern District.*

No.	Lake	Date	Hour	Disc	Color	Cos. r	Cal. cm² Min.	% at 1 m.	Transmission				1% at Meter
									1–2	2–3	3–4	4–5	
1	Beasley	Aug. 16, 1912	10.30—11.02	3.0	--------	91	1.63	16.2	55	54	55	55	5.5
		Sept. 5, 1918	9.55—10.33	5.3	8	85	1.42	25.8	58	60	59	63	7.1
2	Columbian	Aug. 24, 1918	9.42—10.08	2.1	--------	86	1.08	27.5	59	66	66	64	9.5
3	Crystal	July 22, 1913	1.20— 2.00	--------	--------	92	1.49	25.5	54	59	55	--------	6.6
4	Devils	Aug. 31, 1917	2.37— 3.09	10.4	--------	86	0.92	29.0	68	72	77	80	11.7
		Aug. 26, 1919	9.10— 9.45	8.0	6	--------	1.31	29.5	67	70	72	76	12.1
		June 3, 1926	11.09—11.23	9.6	0	--------	1.03	30.6	64	69	65	72	11.2
5	Elkhart	July 22, 1913	9.58—10.10	3.1	--------	93	0.86	29.2	69	73	69	71	10.7
		Aug. 26, 1918	9.14—10.05	3.5	6	86	0.73	33.6	66	71	74	75	11.2
6	Garvin	Aug. 29, 1913	2.09— 2.12	2.4	--------	86	1.24	17.3	54	--------	--------	--------	5.6
7	Geneva	June 28, 1913	10.10—11.55	4.8	--------	94	1.22	29.1	58	64	72	73	10.6
		June 28, 1918	1.45— 2.20	9.2	--------	91	0.96	30.3	68	70	71	72	11.4
8	Green	Aug. 15, 1912	10.57—11.37	3.3	6	90	1.22	25.0	56	56	61	62	7.3
		Aug. 22, 1913	8.39— 9.00	4.3	--------	82	0.86	28.4	55	--------	--------	--------	--------
		Aug. 14, 1919	1.00— 1.43	5.8	--------	90	0.74	28.5	67	69	71	73	11.4
		Aug. 20, 1918	1.04— 1.30	3.1	--------	90	1.04	23.3	68	70	69	65	9.0
		Aug. 21, 1921	2.50— 3.18	3.7	--------	81	1.33	26.6	65	65	70	71	10.1
		Aug. 23, 1921	12.03—12.30	3.6	--------	91	0.93	27.0	60	67	68	68	9.4
		Aug. 24, 1921	11.51—12.30	3.5	6	92	1.14	29.6	64	66	66	66	9.0
		Aug. 9, 1922	10.50—11.24	--------	--------	92	1.20	25.0	59	64	66	73	9.0
		Aug. 5, 1923	9.10—10.00	3.6	--------	86	0.83	30.6	67	67	71	73	10.8
		Aug. 19, 1923	9.25— 9.55	2.9	--------	87	0.84	28.0	61	66	67	68	9.6

9	Kegonsa	July 9, 1913	----	0.9	----	95	1.44	7.2	44	----	----	----	3.5
10	Knights	Aug. 20, 1912	----	4.0	----	91	1.05	22.5	50	50	58	----	6.0
11	Lang	Aug. 16, 1912	----	3.1	----	92	1.39	24.5	46	41	----	----	4.8
12	McCrossen	Aug. 10, 1917	2.32—2.55	2.1	----	84	0.98	27.1	56	56	56	----	7.0
13	Marl	Aug. 21, 1912	9.38—10.20	1.8	----	85	0.92	16.8	51	54	54	53	5.5
		July 19, 1913	9.12—9.43	3.9	----	90	1.20	33.4	67	67	63	62	9.0
		Aug. 25, 1918	8.49—9.30	6.5	----	84	0.59	34.3	76	79	76	76	11.0
14	Mouse	Aug. 29, 1913	11.38—12.06	4.9	----	91	1.40	24.0	68	----	----	----	----
15	Monona	June 2, 1913	11.17—11.40	5.2	----	96	1.40	21.0	55	56	56	53	6.0
16	Nagawicka	Aug. 10, 1919	12.43—12.57	5.9	8	94	1.10	23.9	58	67	65	61	8.7
17	North	Aug. 9, 1919	11.57—12.27	3.0	14	92	1.29	20.2	33	48	48	42	4.5
		Aug. 21, 1919	11.56—12.23	2.5	----	92	1.57	77.9	48	51	48	50	5.0
18	Oconomowoc	Aug. 10, 1919	9.50—10.15	2.8	14	90	1.07	22.2	52	62	62	62	7.2
19	Okauchee	Aug. 9, 1919	2.15—2.26	2.7	8	87	0.98	20.7	51	56	55	55	6.0
20	Otter	Aug. 22, 1918	2.36—2.53	3.3	----	88	1.03	18.7	51	59	58	56	6.1
		Aug. 24, 1918	12.45—1.16	3.3	----	90	0.91	22.7	51	53	61	60	6.5
21	Pine	Aug. 21, 1919	10.23—10.54	5.8	----	90	1.00	27.0	66	67	66	68	9.4
22	Pope	July 19, 1913	11.53—12.14	1.5	----	95	1.40	19.1	18	----	----	----	2.8
23	Rainbow	Aug. 22, 1918	12.17—12.50	----	6	91	1.19	25.5	61	54	55	55	6.7
24	Round	July 21, 1913	10.40—11.10	1.9	----	94	1.43	21.9	67	60	61	61	7.3
		Aug. 24, 1918	10.42—11.09	2.1	6	90	0.95	27.7	63	64	63	64	8.2
25	Taylor	July 24, 1913	11.30—11.55	2.1	----	84	1.33	26.1	56	----	----	----	----
26	Upper Nemahbin	Aug. 10, 1919	2.40—3.09	3.0	12	89	0.88	22.2	54	56	59	58	6.4
27	Adelaide	Aug. 5, 1927	10.21—10.30	3.1	38	89	1.06	11.7	30	37	----	----	3.4
		July 11, 1928	11.40—11.55	2.4	25	95	12.9	12.1	35	41	----	----	3.5
28	Allequash	Sept. 1, 1918	3.03—3.30	1.6	26	77	0.79	10.3	33	33	----	----	3.0
29	Bass	Sept. 3, 1918	10.10—10.32	4.1	8	85	1.01	21.6	52	56	57	59	5.6

TABLE 11—Continued

No.	Lake	Date	Hour	Disc	Color	Cos. r	Cal. cm² Min.	% at 1 m.	Transmission 1–2	2–3	3–4	4–5	1% at Meter
30	Big	July 26, 1926	9.30— 9.47	3.4	8	86	0.72	18.8	50	----	----	----	5.3
31	Blue	Sept. 4, 1918	11.02—11.30	7.2	5	88	1.22	29.8	71	73	74	75	13.3
		June 30, 1926	9.45— 9.51	4.9	8	90	1.05	28.5	64	64	67	66	8.7
32	Clear	Aug. 8, 1928	9.25— 9.50	7.1	0	86	0.99	31.5	74	74	74	74	12.5
33	Clear Crooked	July 19, 1927	1.10— 1.25	3.9	6	93	1.05	30.6	57	58	59	59	7.5
34	Crystal	July 6, 1926	10.20—10.39	8.8	0	93	1.07	39.7	74	81	83	84	34.0
		July 22, 1926	10.14—10.30	8.8	0	90	1.05	35.3	78	80	80	84	17.4
		Aug. 17, 1926	9.18— 9.33	9.5	0	83	0.76	35.4	75	81	78	80	18.7
		July 19, 1927	10.40—10.50	10.7	0	92	1.08	35.8	72	77	79	83	18.8
		June 26, 1928	10.17—10.55	13.6	0	93	1.17	37.5	81	77	81	77	25.8
		July 23, 1928	10.07—10.15	13.0	0	90	1.08	37.6	73	80	81	82	18.6
		Aug. 10, 1928	10.22—10.42	11.0	0	90	1.12	38.6	78	77	74	77	16.6
		Aug. 21, 1928	10.00—10.24	11.0	0	85	0.92	39.0	78	77	74	77	17.1
35	Dead Pike	Aug. 24, 1928	9.00— 9.25	3.7	57	81	0.63	14.3	31	31	----	----	3.3
36	Fishtrap	Aug. 11, 1928	10.20—10.33	2.9	12	90	1.13	15.5	45	45	----	----	4.6
37	High	Aug. 11, 1928	8.40— 8.50	2.0	16	80	0.79	14.8	36	36	----	----	3.6
38	Kawaguesaga	Aug. 31, 1918	9.26— 9.59	2.0	18	82	0.76	18.0	39	41	40	----	4.2
		July 7, 1926	9.35— 9.42	4.2	14	88	0.87	29.4	57	57	66	66	8.3
39	Lost Canoe	Aug. 2, 1927	10.00—10.15	4.3	18	88	1.28	21.1	57	62	60	63	7.4
40	Mary	July 12, 1926	10.30—10.35	2.0	100	92	1.36	6.3	39	----	----	----	3.0
		July 11, 1928	9.35—10.20	1.5	118	90	0.87	4.7	24	----	----	----	2.9
41	Muskellunge	June 29, 1926	10.00—10.06	7.2	0	91	1.09	27.0	60	65	69	70	8.2
		Aug. 9, 1928	1.53— 2.09	5.4	8	56	1.06	24.0	65	67	67	68	8.7
42	Pauto	Aug. 18, 1928	8.43— 8.55	6.3	0	81	0.79	33.5	66	70	70	73	8.7
43	Plum	July 14, 1926	9.00— 9.06	3.4	8	84	0.94	23.9	59	62	63	----	7.7

44	Spider	Aug. 5, 1927	----------	2.0	8	92	1.21	11.3	40	40	40	--------	3.6
45	Star	July 2, 1926	10.20—10.45	4.1	6	90	0.73	25.7	55	66	65	64	8.2
47	Trout	Sept. 1, 1918	11.15—11.44	4.2	6	88	1.19	27.5	62	66	65	66	9.1
		June 29, 1926	12.30—12.45	5.3	6	95	1.28	26.5	63	67	69	71	10.0
		July 22, 1926	12.55— 1.13	5.6	6	93	1.09	32.2	59	69	69	69	9.0
		Aug. 7, 1926	2.45— 2.55	5.1	6	83	0.86	25.1	56	58	69	68	8.0
		Aug. 14, 1926	1.20— 1.30	5.0	6	89	0.86	24.7	62	62	65	68	8.8
		Aug. 24, 1926	9.30— 9.36	5.3	6	83	0.96	25.6	57	57	65	68	8.0
		Aug. 26, 1926	2.10— 2.20	5.3	6	83	0.88	23.0	69	65	65	69	7.5
		June 23, 1927	10.50—11.00	3.7	6	93	1.08	23.5	61	60	--------	--------	7.2
		July 20, 1928	10.30—10.42	5.6	6	92	1.18	26.7	60	62	64	68	8.5
47	Turtle	Aug. 30, 1918	9.51—10.14	2.7	74	84	0.73	10.0	28	--------	--------	--------	2.8
		Aug. 5, 1927	11.00—11.14	1.7	91	92	1.22	4.7	18	--------	--------	--------	1.8
48	Weber	Aug. 13, 1927	1.30— 1.38	8.0	0	89	0.81	34.0	72	72	78	81	16.3
49	White Sand	July 23, 1926	9.10— 9.24	2.6	8	87	0.83	18.7	52	53	--------	--------	5.4
50	Wild Cat	July 11, 1926	10.30—10.37	2.6	16	92	1.09	15.8	28	37	--------	--------	3.6
		June 26, 1927	----------	2.4	18	93	1.06	16.3	38	37	--------	--------	3.9
51	Wolf	July 11, 1927	2.30— 2.47	2.4	26	86	0.79	12.9	22	28	--------	--------	3.0
52	Canandaigua (1)	July 27, 1918	10.37—11.03	4.0	--------	94	1.12	29.1	61	64	62	65	8.6
53	Cayuga (1)	July 29, 1918	2.05— 2.45	5.0	--------	90	1.60	30.0	67	69	68	67	9.4
54	Seneca (1)	Aug. 1, 1918	12.50— 1.23	6.7	--------	94	1.30	32.1	70	72	71	70	11.4
55	Okoboji (1)	July 30, 1919	12.30—12.48	2.8	--------	95	1.31	23.0	54	54	53	--------	6.8

(1) New York, Lat. 42.7°; Long. 76.5°–77.5°. (2) Iowa, Lat. 43.4°; Long. 95.1°.

It should be noted that the new calibration of the thermopile with the hemispherical cover (p. 516) adds 50 per cent to the percentages reported for these lakes at the depth of one meter. See Birge and Juday, '20, '21. It has a similar effect on the calories reported for various depths. The transmission remains the same as reported. The general result is that one per cent of incident radiation is found in Seneca Lake at the depth of 11.4 m. instead of at 10 m., as reported in the earlier paper; in Cayuga Lake the shift is from 8.6 m. to 9.4 m.; in Canandaigua Lake from 7.5 m. to 8.6 m.; in Okoboji Lake from 6.4 m. to 6.8 m. It is of course understood that in stating these depths no great accuracy is claimed for the last figure in the number indicating the depth since it is reached by prolonging the curve of transmission, in most cases through three or four meters.

3. *COMPARISON WITH WORK OF OTHER OBSERVERS*

The Wisconsin Survey seems to have been alone in using the thermopile for measuring the penetration of solar radiation. Other observers have used photometers of various kinds. In all cases the amount of radiation received in air is the basis on which is computed the per cent left at different depths below the surface.

Since these authors deal with light and we with total radiation, some ratio between these two bases must be found, at least provisionally. However "light" may be defined, that part of the solar energy spectrum included in it varies with the altitude of the sun, with the transparency of the air, with the quantity of precipitable atmospheric water, and with other factors. We have obtained a partial notion of this variation from tables kindly furnished us by Mr. F. E. Fowle of the Smithsonian Institution. These enable us to compare this value for air masses 1 to 5 and for 0.5 cm. to 2.5 cm. of precipitable water. The per cent of radiation found between 0.300μ and 0.764μ (practically the *A* line) with air mass 1 and precipitable water 0.5 cm. is about 57.5; with air mass 5 and water 2.5 cm. it is 32.6 per cent; and all intermediate results may be found as these two variables are given different values.

With air mass 1.5 and water 2.0 cm. the value of the radiation in the region named is about 55.7 per cent; and this, rounded off to 56, we have used in comparing our results with those of others. The amount of precipitable water assumed is lower than our summer conditions; and perhaps it would have been as well to assume the rough value of about 50 per cent.

Solar radiation which has passed through one meter of pure water has lost practically all radiation of greater wave length than 0.764μ. If the absorption coefficients of Aschkimass are accepted, between one and two per cent of the radiation left at one meter may come from the region between wave lengths 0.764μ and 0.850μ. If the coefficient of Nichols at 0.779μ is accepted, as in the Smithsonian Physical Tables (p. 307), no appreciable part of the radiation comes from this region. Hence we have repeatedly stated that the radiation measured by the pyrlimnometer at the depth of one meter or more is "practically" all in the form of light, as defined above.

Light may be more narrowly defined so as to exclude radiation from wave lengths shorter than 0.360μ or 0.400μ. In that case the per cent of the total energy spectrum represented by light is correspondingly reduced and a larger per cent of radiation present at the depth of one meter lies in the region thus excluded from light. But it is not necessary to discuss this aspect of the matter further.

From this statement it follows that observations with thermopile and photometer will have certain points of general agreement and difference.

1. The percentage of light radiation shown to be present at any depth by a photometer is greater than the percentage of total radiation shown by the thermopile. The ratio will be variable and dependent on the nature of the photometer and the character of the water; but in clear water the amount of radiation at any depth should be roughly twice as large a per cent of light as of total radiation.

2. The transmission of radiation to the depth of one meter, as measured by the photometer should be correspondingly greater than the transmission measured by the thermopile.

3. The transmission below one meter should be about the same when measured by either type of instrument; unless the selective action of the photometer and the conditions of stain or suspended matter in the water combine to produce a different result. The observations with which ours are to be compared were made in water free from stain and in general with little plankton. A general agreement would be expected in transmission as measured with photometer and thermopile; and in fact such an agreement is present.

Three types of photometer have been used for measuring transmission of radiation in water; the selenium cell, the photographic plate, and the photo-electric cell.

SELENIUM CELL

The earliest photometer to be employed was the selenium cell, which was used by Regnard ('91, p. 216) to measure radiation to the depth of 10 m. in the Mediterranean Sea. One series only is recorded and this shows the defects of the cell as a receiver. As pointed out by Shelford and Gail ('22, p. 144) the results near the surface are too low and at greater depths too high; and they do not require further discussion here.

PHOTOGRAPHIC METHODS

Photographic plates or paper have been used by numerous observers and this method is, no doubt, the best for securing records of the feeble light which penetrates to great depths. The method has not so often been applied to determining the transmission near the surface, meter by meter, and thus obtaining records which can be compared directly with ours. There are three observers whose work may be mentioned, Linsbauer, Klugh and Oberdorfer. Linsbauer ('05) constructed an apparatus for employing under water the photographic methods of Wiesner. He applied it for measuring radiation in the Traunsee, and he, therefore, furnishes one of the few records from fresh water. His mean results follow:

TABLE 12. *Radiation in the Traunsee.*

Depth in meters	0	0.5	1	2	3	5	10
Radiation, per cent	100	29	19	4.9	3.0	1.4	1.4

These results, like those of Regnard are evidently too low near the surface and too high at greater depths. It is possible to imagine conditions under which there might be so rapid and so great an increase of transmission with depth; but such conditions, if present at all, must be very rare, and the series does not show results comparable with ours.

The work of Klugh ('25, '27) is quite different. He devised methods of using photographic plates in an instrument called the ecological photometer; and in certain cases he employed this in the same way that we have used the pyrlimnometer. Klugh's first paper gives a full description of the instrument and its use. It is sensitive to radiation from wave length 0.400μ to the end of the visible spectrum ('27, p. 91).

Two of Klugh's observations may profitably be compared with ours. In his first paper ('25, p. 230) is a series of readings to the depth of 10 m. in the Bay of Fundy near St. Andrews, N. B. His standard of illumination is the radiation at 2 cm. below the surface and the recorded percentages are accordingly higher than would have been the case if the original reading had been taken in air. It is also true that the transmission in the first meter (or 98 cm.) is much greater than would be expected from the transmission below one meter. The per cent at one meter is recorded as 65; while the transmission in the 1–2 m. stratum is 42 and in the meter below it is 44. Below 3 m. the transmission rises, but as there is an evident irregularity in the reading at 4 m. the transmission cannot be calculated in detail. The average transmission between 3 m. and 10 m. is about 53. The situation thus disclosed is quite like that in our less transparent lakes, so far as transmission below 1 m. is concerned. The series might well have come from Lake Mendota at rather less than average transparency down to 3 m. and a little above the average below that depth, down to 10 m.

In the paper of 1927 (p. 91) a similar series is given for Chamcook Lake. This is a lake near St. Andrews, N. B., about 3 miles long and 35 meters deep. It lies "in a granitic region" and is a soft water lake with very clear water and little plankton. Readings were taken at 0.5, 1, 3, 5, and 10 m. The transmission between 1 m. and 5 m. is about uniform at 85; the interval between 5 m. and 10 m. seems to have been slightly less transparent, averaging about 80. If the reading at 10 m. had been 13 per cent instead of 10, the transmission from 1 m. to that depth would have been uniform; and a slight change in the solar radiation might have caused this difference. But, accepting the record, the upper water of Chamcook Lake was nearly as transparent as the clearest strata of our Crystal Lake. Several of our lakes have a transparency as great as that in the 5–10 m. stratum, and the general record is one which we might expect to duplicate in the clearest lakes of northeastern Wisconsin.

Klugh notes that the five readings in this lake required the time from 11:00 a.m. to 3:15 p.m. We have never used photographic methods and will not compare their advantages and disadvantages with those of the thermopile. But the pyrlimnometer has at least the advantage of greater speed. Such a series of 5 readings would be completed in about 10 minutes, if only one reading were taken at each depth.

Oberdorfer ('28, '28a) devised an apparatus for exposing a sensitive paper or film under a neutral-tint wedge, the "Eder-Hechtsche Graukeil." The apparatus is relatively simple and permits rapid work, since a series of 12–14 exposures to the depth of 25 m. can be made in 5–10 minutes. Oberdorfer not only determined the transmission of light, but he also discusses the effect of the shadow of the boat, a matter which we have not investigated. He also made an ecological use of his photometric results by determining the depths within which various species of algae are found and the amount of light which they demand.

Oberdorfer's work was done in the Bodensee (Lake Constance) during two years, January, 1926 to December, 1927 and extended to the depth of 25 m. The highest transmission was found in March, when the average transmission to the depth of 10 m. was 82.1 per meter; to 20 m. it was 82.7. The lowest was in August when the average transmission to 10 m. was 72.2 per meter, and to 20 m. it was 71.7.

Thus the water of the Bodensee has substantially the same transmission as that of our more transparent deep lakes. Our observation in Seneca Lake (table 9) shows that it belongs to the same general class as Lake Constance. The average transmission found in Seneca Lake to 10 m. on August 1 was about 71.3 per meter, practically the same as that found in August by Oberdorfer. There is no reason to doubt that there would be a similarly close correspondence at other seasons.

It may be noted that Oberdorfer found no exceptional loss of light in the surface centimeters of the lake. In this respect his results agree with ours and differ from the observations made in the ocean.

The Photo-Electric Cell

Recent studies with the photo-electric cell have been made by Shelford and Gail ('22, p. 14), Poole and Atkins ('27, p. 177; '28, p. 455), and by Shelford and Kunz ('26, p. 284). Each supplies data which can be compared directly with ours. The instrument which they employed is far more sensitive than the thermopile and their observations extend to much greater depths than ours. Shelford and Gail took readings as deep as 40 m. in Puget Sound; and Poole and Atkins went to depths of 65 m. in the sea near Plymouth, England. Their studies furnish numerous series of observations with whose readings in the upper 10 m. we may compare ours. It will be seen that there is a close general agreement so far as our readings extend and that the deeper readings in the sea show that the general conditions of the upper water continue in the deeper strata.

Shelford and Gail (table 5, p. 155) give the transmission in Puget Sound to the depth of 10 m. as determined from 16 series of observations. Our observations on Crystal Lake, the mean of 6 series, may be compared with theirs in the following table.

TABLE 13. *Per cent of radiation present in Puget Sound (P) and Crystal Lake (C).*

Depth in meters	0	1	2	3	4	5	6	7	8	9	10
P. per cent of light	100	62.4	45.7	36.3	30.0	23.0	18.7	16.1	13.7	11.4	9.5
C. per cent total	100	37.5	28.9	23.2	18.1	14.6	12.0	10.3	8.6	7.2	5.9
C. per cent light	100	67.0	51.6	41.4	32.3	26.1	21.4	18.4	15.4	12.9	10.5

Per cent of Transmission

Meters	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	mean
P.	82	73	79	82	77	80	86	85	86	81
C.	77	80	78	81	82	85	83	83	82	81

In our observations the percentages present are given in terms of total radiation; those of Shelford and Gail in terms of light. We may recompute our results as light, since only short wave radiation remains at depths of one meter and below. We have assigned 56 per cent of the solar energy spectrum to the region between 0.300μ and 0.762μ. This is certainly quite large enough. The results are given in the third line of the above table and they show that Crystal Lake and Puget Sound may yield almost identical results. The transmission meter by meter is also practically the same. Two series from the same water would not be likely to show a closer agreement than do these, of which one is from salt water and the other from fresh. Figure 11 shows the transmission curves corresponding to table 13 and their parallel course is obvious.

Poole and Atkins also worked with the photo-electric cell and their observations extended to 65 m. Both of their papers report series which can be compared with ours. The paper of 1928 reports a larger number of series which they tabulate in detail and show in fig. 3, p. 476. The curves show on a large scale for depth exactly the same phenomena as do ours to the depth of 10 m. They show also that the curves may be essentially straight lines when platted on semi-logarithmic paper, and that in general they continue at greater depths the same course that they have taken in the upper water. They also show the same kind of changes and irregularities of transmission that we have found at our lesser depths. The series reported in 1928 fall into two groups, one with low transmission and one with high.

We may compare the average transmission of some of our lakes with that in the upper 10 m. of the curves in the group with low transmission. The average transmission in these cases, when measured over a straight run of 6 m. to 9 m. is from 68 to 77. The lowest is found in series 12 and 13, where transmission is from 68 to 71; that of Nagawicka,

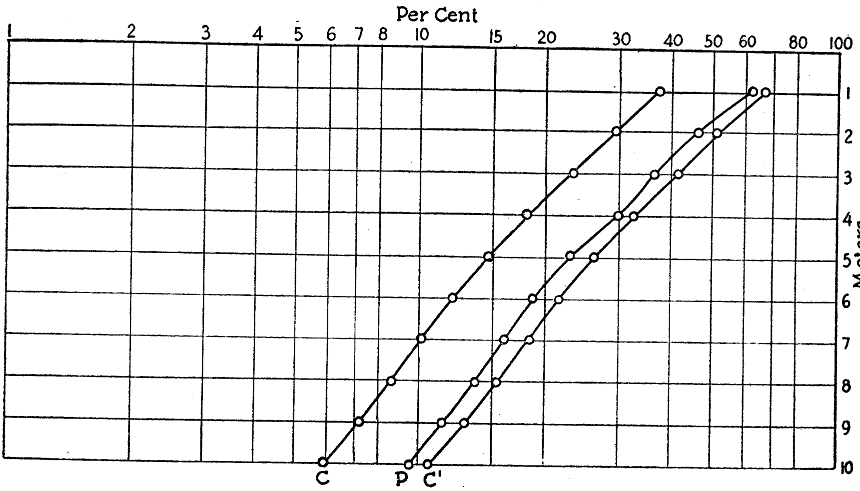


FIG. 11. Transmission curves of radiation in the water of Puget Sound and of Crystal Lake, Wisconsin. The curve from Puget Sound (P), is the mean of 16 series of observations by Shelford and Gail; that from Crystal Lake (C) is the mean of 6 series, reported in table 9. The curves are parallel, but the percentages determined by the pyrlimnometer are lower than those by the photo-electric cell, since one set is based on total solar radiation and the other on light. In the curve marked C′ the percentages from Crystal Lake are re-computed as light, assigning 56 per cent of solar radiation to light.

Pine, and Cayuga lakes is just below 70 and readings of about 70 are found in Green, Trout, and Seneca lakes. Series 11 and 14 show a transmission of 74–75, about like that reached by Devils, Elkhart, and Geneva lakes. Series 9 has about 77 which compares with the upper part of Marl Lake.

In the other group of series (16–22) in the report of Poole and Atkins—that with high transmission—the per cent ranges from 85 to 90. This is a condition reached only by Crystal Lake in our list, and is reached by that lake only under conditions of exceptional clearness. (See table 9). The lake belongs to the same type, but only just reaches it.

In nearly all of our lakes the transmission in the 2–3 m. stratum is smaller than that below. (See fig. 7). This is notably true also of certain series reported by Poole and Atkins, such as series 13 and 14. In other cases this condition is not present. Less uniform conditions of transmission would be expected in our lakes, small and without currents, than in the sea with its large waves and vigorous currents due to wind and tide.

In 1925 observations with various types of photo-electric cells were made by Shelford and Kunz in Lake Mendota to the depth of 10 m. Their paper ('26, p. 290) shows the transmission meter by meter as measured by different cells and with various ray filters. The results are also shown in fig. 9, p. 298. The transmission is much the same as is shown by the pyrlimnometer. The readings of the potassium cell without a ray filter show transmission from 33 to 66; a result quite comparable to ours, although the curve is unusually irregular.

It thus appears that the photometer and the thermopile give similar results when employed for the measurement of the transmission of radiation through the water of lakes. Transmission is of the same order of value and platted transmission curves run parallel whenever observations by the two types of receiver are compared. This is true for waters devoid of stain and with little plankton. No readings have been made with the photometer in lakes with deeply stained water, and only one series in Lake Mendota, the lake which may represent the larger part of those which we have studied.

There remains to be compared the transmission in the upper meter of the water as measured by photometer and thermopile. On this transmission, combined with the losses at the surface, depends the per cent recorded as present at one meter. The two types of instrument yield different results and different forms of photometer should also give different results, according as their sensitivity extends more or less into the red end of the visible spectrum. In any case the thermopile must give a smaller per cent, since in air it registers the total solar radiation, which is about twice as great as the radiation in the form of light, and of which almost all except the light is lost in the first meter.

In table 13 and figure 11 the transmission curve of Crystal Lake is transposed from the basis of total solar radiation to that of light radiation. The part of the spectrum between 0.300μ and 0.762μ is reckoned as light and computed as 56 per cent of the total radiation. This change brings the curve for Crystal Lake very close to that for Puget Sound, but the apparent correspondence is closer than is warranted by the probable facts. The red part of the spectrum, included by us in the 56 per cent designated as light, is rapidly absorbed by water, while the photo-electric cell responds only to those wave lengths to which water is most transparent. It would seem, therefore, that the per cent reported by Shelford and Gail is too low or else ours is too high. Poole and Atkins ('25, p. 195) suggest that low readings may be caused by the concave lens formed by the water-glass surface of the photo-electric bulb used by Shelford and Gail. We have already said that our readings are probably too high as a result of leaving the diffuse radiation out of account.

The transmission curves of the series reported by Poole and Atkins may be extended upward to one meter from the depth of 1.1 m. to 1.5 m. where the upper reading was made. In that case the curve for series 14 shows that about 37 per cent of total illumination was present at one meter. Series 16 gives about 70 per cent at that depth and series 6 from the paper of 1927 about 75 per cent. The others would come between these extremes. These figures would correspond roughly to 20–35 per cent of total radiation as shown by the pyrlimnometer and such a rough correspondence is indicated in the several cases whose transmission has just been discussed. It is not worth while to say more on this subject at present, especially as both of the papers reporting the results of using the photo-electric cell record also large losses of light at the surface. This part of the subject has not been especially investigated in our work. The readings which we have taken in several cases at the depth of 10 cm. have not disclosed any such large and irregular losses at the surface as those reported by Shelford and Gail; but our observations are by no means numerous enough to constitute a study of the subject.

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APPENDIX

DETERMINATION OF THE MEAN PATH OF RADIATION IN LAKE MENDOTA.

By the "mean path of radiation" we understand the average distance through which solar radiation travels in passing through a stratum of lake water one meter in vertical thickness. This mean path may be computed for radiation delivered to the lake during any desired period of time. If all radiation came direct from the sun and if the sun were fixed in the sky, this path would be the secant of the angle of refraction for parallel rays reaching the surface of the lake from the sun. But since radiation is both direct and diffuse and since the sun constantly travels over the sky, the problem of the mean path is more complicated.

Since one main purpose of the study of radiation was to ascertain the effect of direct insolation on the warming of lakes, it was advisable to determine this mean path for the warming period of Lake Mendota. This incidentally involves the solution for 5 months of the year, April to August inclusive.

The general result is to assign to the radiation reaching the lake during this period a mean path in the water of about 116 cm. in passing through a stratum 100 cm. in vertical thickness. This corresponds to the path of direct radiation from the sun at the altitude of about 47.5°. In tables 2, 7, and 8, this result is employed and is referred to as "mean sun". This expression agrees in form with "zenith sun" in the same tables and means that all radiation is regarded as direct, and that during the warming period such radiation has an average path corresponding to that from the sun at the altitude stated above. The application of this result to Lake Mendota is explained on p. 546.

The following statement gives an account of the method of computation.

A. The warming period of Lake Mendota is taken as extending from April 15 to August 15. The earlier day marks the mean date when the lake reaches the temperature of 4.0° C.; there is usually no increase of temperature after the middle of August.

B. The records of the United States Weather Bureau at Madison show (1) the total radiation received from sun and sky on a horizontal surface. This is recorded automatically by a Callendar sunshine recorder and is stated in calories per square centimeter per hour. (2) The duration of sunshine, recorded automatically by a Marvin sunshine recorder and stated in the records as per cent of sunshine for each hour of the day.

C. In the record sheets from April to August, inclusive, and from 1911 to 1920 inclusive, all hours were marked in which sunshine was recorded for the entire hour. From these data was computed the value of a mean sunshine hour for each hour of each day and each month. The records of the Weather Bureau show the mean per cent of sunshine for each hour of each month. Hence could be computed the amount of radiation received from sun and sky during each hour. The difference between this amount and the total radiation recorded is that received from sky during cloudy hours. It was assumed that the radiation from cloud came in equal amount from each unit area of sky. See Fig. 12 and table 15.

D. The mean altitude of the sun for each hour of each month was determined from tables giving the altitude for each hour on the 1st, 10th, and 20th of each month.

E. The mean hourly radiation from sun and sky was platted as a curve on coordinate paper and the curve of the sun's altitude was platted on the same sheet. The amount of radiation received between successive intervals of solar altitude was thus determined. See Fig. 12 and table 16.

F. The percentage of sky radiation was computed from data given by Kimball ('19, p. 777) as follows:

Altitude of sun -----	60.0°	41.7°	30.0°	23.5°	19.3°	14.3°	10.2°
Per cent from sky	16	16	19	21	24	27	37

The per cent of radiation reflected from the surface of the lake was computed from data given by Schmidt ('15, p. 171) as follows:

Altitude of sun	90°	80°	70°	60°	50°	40°	30°	20°	10°	0°
Per cent reflected	2.04	2.04	2.06	2.14	2.45	3.36	5.97	13.35	34.79	100.0

The loss of diffuse radiation by reflection, assuming that unit areas of sky send out equal quantities of radiation, is 17.3 per cent (Schmidt, 15, p. 176).

G. The length of the path of direct radiation in reaching the depth of 100 cm. below the surface was computed for sun's altitude 5°, 15°, etc.

H. From these data the mean path of direct radiation was determined for each month and for the whole period. (Tables 17 and 18.)

I. The diffuse radiation was computed on the assumption that equal areas of sky send out equal amounts of radiation. The hemisphere was divided into 10° zones whose area was determined; the percentage reflected and the path in the water was computed for the center of each zone. The mean path of diffuse radiation was thus determined as 119 cm. in reaching the depth of 100 cm. below the surface. See Poole and Atkins '27, p. 184, table 1.

J. For direct radiation and for direct and diffuse combined the results are shown in the following table.

TABLE 14. *Mean path of radiation, April–August.*

Month	Path, direct	Per cent, direct	Per cent, diffuse	Resulting path
April	119	72.0	24.0	119
May	116	76.4	23.6	117
June	113	75.7	24.3	114
July	114	77.8	22.2	115
August	118	74.9	25.1	118
Mean	115	76.8	23.2	116

The mean path for the period is based on the mean path and the mean number of calories received during each month. It may be more exactly stated as 115.9 cm. If the period is limited to April 15–August 15 the mean path is 115.6 cm.

K. This computation is evidently approximate. The division between sun and cloud is not very accurately given by the Marvin recorder, which records "Cloud" when the sun does not cast a shadow, and the amount of illumination at which the sun ceases to cast a shadow is determined by the judgment of the observer. It is approximately true that equal areas of sky send out equal amounts of radiation when the sky is covered by a uniform layer of clouds; but this is by no means true when the sky is partly covered by clouds, whether these obscure the sun or not. The estimated percentages of sky radiation assume a sky free from clouds. There seem to be no measurements of sky radiation under average conditions of mixed sky and cloud, or with haze and smoke. Kimball's estimates of sky radiation are, therefore, lower than average figures would be. Increase of the per cent of sky radiation would reduce correspondingly the amount of direct radiation, and would increase the amount reflected and the mean path in the lake.

On the other hand, if all radiation were diffuse the mean path would be 119 cm.; if all were direct the mean path for any month in the period would not be less than 113 cm. (table 14) and for the whole period it would be about 115 cm. Thus, the possible error in the accepted result of 116 cm. cannot be so great as seriously to affect the purposes for which it is used. It will be found that any reasonable assumption as to the ratio between direct and diffuse radiation will leave the result close to 116 cm. The same may be said of the results given for the single months in table 14.

L. We have not studied the change of direction of radiation and consequent change of length of path, due to dispersion by particles suspended in the water. We have not considered the matter of radiation directed upward or laterally in the water.

M. Figure 12 and the following tables are added in order to show the methods of computation in certain cases. Figure 12 shows the diagram from which is derived the distribution of calories in June by altitude of sun. The computation is made for a mean day and the total calories given in table 16 are derived from this result. Table 15 shows the computation for June.

In this table the data given under "per cent of sunshine" and "total calories" are taken from the records of the United States Weather Bureau. "Calories, full sunshine" are computed as stated in this note. "Calories, cloud" are derived by difference.

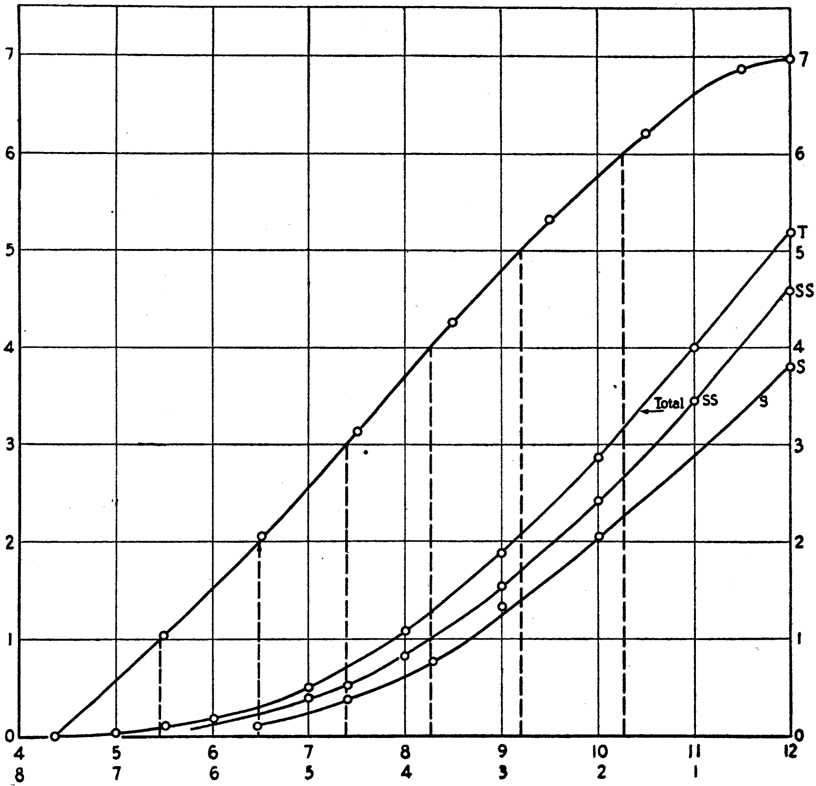

FIG. 12. Distribution of calories by hour and by altitude of sun, mean day, June, 1911–1920. The upper curve gives the course of the sun; T represents total calories; S represents calories from sun; and SS represents those from sun and sky. Calories for the corresponding hours of morning and afternoon are combined; the day is divided by sun time. The time is given at the bottom of the diagram; the numbers 1, 2, etc. on the side represent hundreds of calories or successive increases of 10° in the altitude of the sun. Verticals drawn from the solar altitude line intercept on the calorie lines the number received during the passage of the sun through the 10 degree intervals.

TABLE 15. *Computation of mean daily calories for June 1911–1920.*

Hour ending	5	6	7	8	9	10	11	12	
Calories, full sunshine	1.5	10.5	25.6	40.9	55.3	61.9	69.1	71.3	
Per cent of sunshine	50.6	51.1	54.6	57.7	64.4	70.4	72.9	78.4	
Calories, sun and sky	0.8	5.4	14.0	23.6	35.6	43.6	50.4	55.9	
Total calories	0.9	7.4	18.6	30.2	40.5	48.8	55.3	59.2	
Calories, cloud	0.1	2.0	4.6	6.6	4.9	5.2	4.9	3.3	------
Hour ending	1	2	3	4	5	6	7	8	Total
Calories, full sunshine	70.9	67.7	59.7	49.3	35.6	21.4	8.5	1.0	649
Per cent of sunshine	80.2	78.9	75.8	70.0	62.5	53.9	45.3	42.2	
Calories, sun and sky	56.9	53.4	45.3	34.5	22.3	11.6	3.8	0.4	458
Total calories	57.9	55.6	49.7	40.3	29.3	16.7	6.4	1.0	521
Calories, cloud	2.8	2.2	4.4	5.8	7.0	5.1	2.6	0.6	63

TABLE 16. *Calories received by Lake Mendota from sun and sky and from cloud.*

Sun's Altitude	April	May	June	July	August	Total
Below 10	120	186	120	62	62	550
10 —20	390	496	480	517	558	2,451
20 —30	870	930	960	1,116	930	4,806
30 —40	1,620	1,581	1,380	1,395	1,612	7,588
40 —50	2,490	2,077	2,010	2,635	2,604	11,816
50 —60	4,650	3,348	2,610	2,720	5,611	19,939
60 —70	----------	4,309	6,180	5,394	713	16,596
Total sun and sky	10,140	12,927	13,740	14,849	12,090	63,746
Cal. from cloud	1,980	1,550	1,890	1,560	1,760	8,740
Total calories	12,120	14,477	15,630	16,409	14,850	72,586

TABLE 17. *Computation of direct radiation and its path in the lake.*

Total calories	Per cent sun	Calories sun	Per cent to lake	Calories to lake	Per cent	Path	Result
550	50.0	275	44.0	121	0.2	1.51	0.3
2,451	72.0	1,756	77.4	1,359	2.6	1.45	3.8
4,806	79.0	3,797	92.0	3,493	6.8	1.36	9.2
7,588	82.5	6,260	95.6	5,985	11.6	1.27	14.7
11,816	84.0	10,925	97.2	10,619	20.6	1.18	24.3
19,939	84.0	16,749	97.7	16,354	31.7	1.11	34.9
16,596	84.0	13,941	97.9	13,648	26.2	1.06	27.8
63,746		53,703		51,579			115.0

Notes— "Total calories" are taken from table 16.
"Per cent sun" comes from Kimball's data p. 000.
"Per cent to lake" equals 100 per cent less the percent reflected.

TABLE 18. *Final computation of mean path.*

Calories from cloud	8,740
Calories from sky	10,043
Total diffuse radiation	18,783
Reflected at 17.3 per cent	3,249
Diffuse radiation to lake	15,534, or 23.2 per cent
Direct radiation to lake	51,579, or 76.8 per cent
Path, diffuse radiation	119 cm.
Path, direct radiation	115 cm.
Mean path	115.9 cm.

A PRELIMINARY REPORT ON THE GROWTH OF THE ROCK BASS, AMBLOPLITES RUPESTRIS (RAFINESQUE), IN TWO LAKES OF NORTHERN WISCONSIN.[1]

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I. INTRODUCTION

For several years the Wisconsin Geological and Natural History Survey has been making a limnological study of lakes in the northern part of the State. Because of the fact that so much has been learned of the physical, chemical and biological conditions in these lakes, the region seems particularly favorable for a study of the growth rates of fishes in relation to environmental factors.

The U. S. Bureau of Fisheries undertook such a study in the summer of 1927 and continued the collection of material in the summer of 1928. Other duties have prevented the writer from spending all of his time on the problem so that much of the material has not been examined. However, work on the rock bass collected in Trout and Muskellunge Lakes during both summers has been completed, and since the Bureau has found it necessary to discontinue the investigation for the time being, it seems advisable to publish a preliminary report of the results.

The data are admittedly inadequate and any conclusions reached must be tentative. The number of individuals and the number of age groups represented must be greatly increased to form the basis of final conclusions. The Wisconsin Geological and Natural History Survey plans to continue the work and we may confidently expect further information on the growth of the rock bass.

No attempt has been made to correlate growth of the rock bass with environmental factors. The data of this paper

[1] Published by permission of the U. S. Commissioner of Fisheries.

indicate that, in all probability, local races exist among the rock bass of Trout Lake, and that each race has its own characteristic growth rate. If this is true, then it is apparent that in order to correlate the growth of the fish with factors in the environment, it is necessary to study these factors at each collecting station. In the lakes considered here, limnological observations were made only in the deeper areas and not in the protected, shallower areas where the rock bass were captured.

The writer takes this opportunity of thanking Mr. Chancey Juday, who suggested the problem and made available equipment and space in the field laboratory of the Wisconsin Geological and Natural History Survey at Trout Lake. Dr. John Van Oosten, U. S. Bureau of Fisheries, by his suggestions and critical examination of the data, has made an invaluable contribution to the work. Thanks are also due Dr. Carl L. Hubbs, Curator of Fishes, University Museums, University of Michigan, who has offered many helpful suggestions.

II. The Lakes

Trout and Muskellunge Lakes are situated in morainal basins in the western part of Vilas County, Wisconsin. Trout Lake is much the larger and deeper, but in many respects the two lakes are similar—both are deep enough for thermal stratification and both have rather extensive areas covered with large aquatic plants.

The following data on Trout Lake have been taken from Juday (1914):

Location: Towns 41 and 42 North, Range VI and VII East.
Length: 7.24 km. (4.5 miles) in N–S direction.
Width: 3.86 km. (2.4 miles).
Area: 16.83 sq. km. (6.5 sq. miles).
Depth: 35 meters (115 feet).

No data have been published on Muskellunge Lake; the information given below was taken from the unpublished records of the Wisconsin Geological and Natural History Survey:

Location: Town 41 North, Range VII East.
Length: 3.3 km. (2.05 miles) in NE–SW direction.
Width: 1.18 km. (0.73 miles).
Area: 3.74 sq. km. (1.45 sq. miles).
Depth: 19.3 meters (63.3 feet).

III. Materials and Methods

Most of the fish were taken in gill nets of various sizes of mesh. It was found that seines could not be used effectively because of snags along the shores, although a few fish were taken by this method. A small number of fish were also captured by hook and line.

With few exceptions, the fish captured in Trout Lake during 1927 were taken in Blaisdell's Bay, which is located at the extreme southeast corner of the lake, between the point of land known as Rocky Reef and the mainland on the east. In 1928 the collections were made on Camp Franklin Shoal, which is located between Crescent Island and the mainland at the point on which Camp Franklin is situated. The shoal is approximately one mile west of Blaisdell's Bay, from which it is separated by Rocky Reef and an area overlain by relatively deep water.

With the exception of a few individuals, the fish in Muskellunge Lake were taken along the north shore between the Musky Cottages on the east and Camp Osoha on the west. So far as is known there are no barriers which would prevent migration of the fish along this shore.

Standard length measurements in millimeters were made on a measuring board similar to the one described by Thompson (1916), and a sample of the scales of each fish was taken for age determination. No weights were recorded for the 1927 fish, but in 1928 weights were determined in grams by means of a Chatillon balance. These data are not included in this report.

The method known as the scale method was used to determine age and growth rates. The reader may refer to Van Oosten (1923 and 1929) and to Creaser (1926) for a discussion of the method. Up to the present, no one has tested the soundness of the scale theory on the rock bass, but since Creaser (1926) has found it usable for the closely related pond sunfish, *Eupomotis gibbosus,* and since other authors have found it valid for many species of fish, the writer has accepted it as valid here.

Scales were mounted in a glycerine–gelatine jelly on microscopic slides and the image projected, at a magnification of about 40, on the ground-glass plate of the apparatus described by Van Oosten (1923). The rock bass has a typical ctenoid scale and the annuli are readily located on most of the scales. Of the 418 scale samples examined, 22 were discarded because the age could not be determined with confidence. Although most of the discarded scales were taken from fish which belonged in age groups discussed in this paper, the number discarded (5.2%) is considered too small to affect the results markedly.

In order to calculate the length of a fish at the end of each year of its life, measurements were made of the distance of each annulus and the border of the scale from the focus. The measurements were made to the nearest millimeter along the anterior radius. The border of a scale was taken to be the outermost circulus, thus excluding the clear marginal area. In making calculations, the following formula was employed:

$$L_1 = \frac{L \times S_1}{S},$$

where L_1 = length of the fish at the end of year N, L = length of the fish at the time of capture, S_1 = length of anterior radius of scale at end of year N, and S = length of anterior radius of scale at the time of capture. This formula is believed to give only approximate results since it is based on the assumption that the anterior radius of the scale of the rock bass increases in length proportionately with the length of the fish, which assumption is probably only approximately true. No correction was made for Lee's phenomenon or for the fact that the fish attains a certain length before forming scales. Since only relatively old fish are employed, Lee's phenomenon may not be an important factor in the calculated length data.

Ages are designated by Roman numerals; a fish taken in the first summer of its life and which shows no annulus on its scales, belongs to age group I; a fish taken in the second summer of its life and which shows one annulus belongs to age group II.

IV. Discussion

a. Selection of data

Tables 1 and 2 give the number of fish in each age group taken from Trout and Muskellunge Lakes in 1927 and 1928, with the exception of 22 fish which were discarded because their scales could not be read with confidence.

TABLE 1. *Trout Lake. Number of fish in each age group taken in 1927 and 1928.*

Year	Number of fish in age groups:											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	Totals
1927	1	2	1	0	30	14	26	14	4	2	1	95
1928	3	0	1	1	0	25	16	13	1	2	0	62
Totals	4*	2*	2	1	30	39	42	27	5	4	1	157

*Taken in seine.

TABLE 2. *Muskellunge Lake. Number of fish in each age group taken in 1927 and 1928.*

Year	Number of fish in age groups:											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	Totals
1927	0	0	0	0	2	25	45	21	9	6	2	110
1928	0	0	0	2	0	38	29	36	21	3	0	129
Totals	0	0	0	2	2	63	74	57	30	9	2	239

It is evident that most of the fish fall into a few age groups in each collection, a fact which is explained by the selective action of the gill nets. The obvious difference in age composition of collections from the two lakes will be commented on later. Not only does a gill net select fish of certain lengths, but it seems certain that it selects the smaller individuals of the oldest and the larger individuals of the youngest age group taken. Such selected individuals are not representative of their year classes and must be discarded in a study of the average growth rate of a population. Not only must representative age groups be chosen, but for a comparative study, only those representative age groups which were taken in adequate numbers in both lakes. On this basis, fish of age groups VI, VII and VIII seem to meet the requirements for a comparative study.

There may be some question whether the fish of age group VI in the four collections are really representative of their respective year classes. In the 1927 collection from Trout Lake, fish of age group V are discarded and it follows that the fish of the sixth age group are in all probability representative. No fish of the fifth age group were taken in the 1928 collection, but the sixth age group is considered representative because the average length of the VI–year fish at the time of capture is greater than that of the VI–year fish of the 1928 collection from Muskellunge (tables 4 and 6). Since gill nets of the same size mesh were used in both lakes, it seems probable that V–year fish, with an average length less than that of the VI–year fish, would have been taken in Trout Lake, had they been present. The fact that only two V–year fish were taken in the 1927 collection from Muskellunge Lake suggests that the VI–year fish are not representative. If this were true, then the assumed fact that the VI–year fish were the larger individuals of their year class, combined with the influence of Lee's phenomenon, should make their calculated lengths greater than those of the same year class (age group VII) of the 1928 collection. Comparison of the calculated lengths of age group VI (table 5) and age group VII (table 6) does not support this contention. It might also be claimed that the VI–year fish of the 1928 collection from Muskellunge Lake were the larger individuals of their year class, but the calculated length data in table 6 give no evidence to support the claim.

b. Typical growth curve

Tables 3, 4, 5, and 6 show the average actual and calculated lengths, in millimeters for each year of life, for fish of age groups VI, VII and VIII taken from Trout and Muskellunge Lakes in 1927 and 1928 respectively. They also show, for each year of life, the averages resulting from combining the calculated lengths of all three age groups, and the average annual increments derived from these calculated lengths.

TABLE 3. *Trout Lake, 1927. Number of fish, average actual and calculated lengths in millimeters, combined average calculated lengths and annual increments for fish of age groups VI, VII and VIII.*

Age Group	No. of fish	Actual length	Calculated length at end of growth years:						
			1	2	3	4	5	6	7
VI	14	120	20	37	56	81	109	------	------
VII	26	141	21	40	63	82	113	136	------
VIII	14	151	17	38	59	84	109	134	148
Average--------	54	----------	20	39	60	82	111	135	148
Annual increment---------	54	----------	20	19	21	22	29	24	13

TABLE 4. *Trout Lake, 1928. Number of fish, average actual and calculated lengths in millimeters, combined average calculated lengths and annual increments for fish of age groups VI, VII and VIII.*

Age Group	No. of fish	Actual length	Calculated length at end of growth years:						
			1	2	3	4	5	6	7
VI	25	111	19	33	49	71	96	------	------
VII	16	115	18	32	45	61	80	102	------
VIII	13	141	21	39	55	74	97	119	136
Average--------	54	----------	19	34	49	69	91	110	136
Annual increment---------	54	----------	19	15	15	20	22	19	26

TABLE 5. *Muskellunge Lake, 1927. Number of fish, average actual and calculated lengths in millimeters, combined average calculated lengths and annual increments for fish of age groups VI, VII and VIII.*

Age Group	No. of fish	Actual length	Calculated length at end of growth year:						
			1	2	3	4	5	6	7
VI	25	115	19	36	53	80	98	------	------
VII	45	130	20	38	58	78	103	123	------
VIII	21	145	18	35	54	75	100	125	140
Average--------	91	----------	19	37	56	78	101	123	140
Annual increment---------	91	----------	19	18	19	22	23	22	16

TABLE 6. ***Muskellunge Lake, 1928. Number of fish, average actual and calculated lengths in millimeters, combined average calculated lengths and annual increments for fish of age groups VI, VII and VIII.***

Age group	No. of fish	Actual length	Calculated length at end of growth year:						
			1	2	3	4	5	6	7
VI	38	95	22	37	54	71	91	------	------
VII	29	118	20	38	55	76	96	115	------
VIII	36	136	19	37	56	76	101	120	134
Average	103	----------	20	37	55	75	96	118	134
Annual increment	103	----------	20	17	18	20	21	22	16

Examination of the grand averages of annual growth increments for the four collections brings out certain general features of the growth history of the rock bass. It will be seen that the second year invariably shows a decline in rate of growth over the first year; that in general the increments later increase progressively to the highest point in the fifth year of life (in the sixth year in table 6), and then, with one exception (table 4), decline to the lowest point in the seventh year. Thus, the growth curve typically has the form of a double sigmoid (fig. 1). The curves shown by Creaser (1926, fig. 11) indicate the same type of growth for the pond sunfish, *Eupomotis gibbosus*. Virtually all age groups (table 7, this paper), though not all individual fish, show this type of growth, so it may be stated that, in general, the double sigmoid growth curve is characteristic of the rock bass. The exception noted in table 4, where the grand average increments reached the highest rather than the lowest point in the seventh year, is explained by the unusually slow growth of the VII–year fish throughout life. This slow growth resulted in a lowering of the grand averages of calculated lengths, and consequently of increments, for each year of life except the seventh. The average annual increments of this VII–year group (table 7), however, exhibit the typical rock bass growth curve.

The grand average increments show further that the second hump of the double sigmoid curve, which usually reaches its highest point in the fifth year of life, is greater than the first, which occurs in the first year of life. That is, the grand average increments of the fifth year of life are consistently greater than those of the first year; and with two exceptions (tables 4 and 6) are greater than those of any other year of life. Table 7 shows that in six of the twelve age groups the greatest growth occurred in the fifth year, and that of the remaining six age groups, in five the greatest growth occurred in the fourth or sixth years, or was equally great in the fifth and sixth, or in the fourth, fifth and sixth.

This fact is more strikingly demonstrated from a different point of view in table 8, which shows the distribution of individual fish of age groups VII and VIII according to the year of life in which the greatest growth occurred. The fish of age group VI were not included in the table because individuals of that age had no opportunity to demonstrate their rate of growth in the sixth year of life. If included, they would only contribute to the number having the greatest growth in the first five years of life. It appears proper to include the VII–year fish for the reason that not a single VIII–year fish grew most rapidly in its seventh year of life. It will be seen that, of the 200 fish, 73 (37%) grew most rapidly in the fifth year of life, 54 (27%) grew most rapidly in the sixth year, and 34 (17%) in the fourth year. Only 39 (20%) of the 200 fish showed the most rapid growth in years other than the fourth, fifth and sixth.

TABLE 7. *Trout and Muskellunge lakes, 1927 and 1928. Average growth increments, by age groups, of fish in age groups VI, VII and VIII.* (Data derived from average calculated lengths in Tables 3, 4, 5 and 6).

Lake	Year	Age group	Average annual growth increment in years:						
			1	2	3	4	5	6	7
Trout	1927	VI	20	17	19	25	28	------	------
		VII	21	19	23	19	31	23	------
		VIII	17	21	21	25	25	25	14
	1928	VI	19	14	16	22	25	------	------
		VII	18	14	13	16	19	22	------
		VIII	21	18	16	19	23	22	17
Muskellunge	1927	VI	19	17	17	27	18	------	------
		VII	20	18	20	20	25	20	------
		VIII	18	17	19	21	25	25	15
	1928	VI	22	15	17	17	20	------	------
		VII	20	18	17	21	20	19	------
		VIII	19	18	19	20	25	19	14

TABLE 8. *Trout and Muskellunge lakes, 1927 and 1928. Distribution of individual fish of age groups VII and VIII according to the year of life in which greatest growth occurred.*

Lake	No. of fish	Number of fish showing greatest increment in growth year:						
		1	2	3	4	5	6	7
Trout	69	6	1	2	9	29	22	0
Muskellunge	131	14	4	12	25	44	32	0
Total	200	20	5	14	34	73	54	0
Per cent of total	100	10	3	7	17	37	27	0

In most fresh-water fish the most rapid growth takes place in the early years of life and there is a progressive decrease with increase in age. Two explanations have been offered for the occurrence of rapid growth at a relatively late period in the life of the rock bass. The growth curves shown by Creaser (1926, fig. 11) seem to indicate that the most rapid growth of the pond sunfish occurs in the two years just preceding that in which sexual maturity is reached. There is a possibility that an internal adjustment associated with the approach of sexual maturity would result in an increase of the rate of growth, but there are no data on the rock bass which bear on that question. Another suggestion offered is that when the rock bass attains a certain length, there is a change in the type of food eaten, which results in an increase in the growth rate.

Whatever the true explanation for rapid growth relatively late in life may be, there is some evidence that the influence of conditions in the environment may determine the particular year in which the most rapid growth takes place. More individual fish from Muskellunge Lake grew most rapidly in 1925 than in any other calendar year covered in the collections. Nineteen of 25 VI–year fish, 19 of 45 VII–year fish, and 11 of 21 VIII–year fish of the 1927 collection; 4 of 38 VI–year fish, 10 of 29 VII–year fish, and 14 of 36 VIII–year fish of the 1928 collection grew most rapidly in the calendar year 1925. In this respect the remaining fish are well distributed through the other calendar years. Trout Lake fish give no evidence of having grown most rapidly in 1925 or in any other calendar year, and since a favorable year for Muskellunge Lake rock bass would, in all probability, be equally favorable for those in Trout Lake, the evidence cited is not regarded as highly significant.

c. Comparison of growth rates of populations in in Trout and Muskellunge Lakes

A comparison of the average calculated lengths of the age groups taken from Trout Lake in 1927 (table 3), with corresponding age groups taken in the same year from Muskellunge Lake (table 5), shows that, in every year of life and in each of the three age groups, the Trout Lake rock bass attained the greater length. The grand averages of calculated lengths in these tables (see also curves A and B, fig. 1) point to the same conclusion: that the rock bass of Trout Lake grew more rapidly than those of Muskellunge Lake.

A comparison of the average calculated lengths of the age groups taken from Trout Lake in 1928 (table 4), with the corresponding age groups taken from Muskellunge Lake in the same year (table 6) shows that, on the whole, the rock bass of Muskellunge Lake grew more rapidly than those of Trout Lake. An examination of the grand averages in these tables (see also curves C and D, fig. 1) corroborate this conclusion. Thus it appears that the data of 1927 and 1928 conflict.

If we compare now, for each lake, the growth data of corresponding age groups and the grand averages of these growth data, for fish taken in 1927 with those for fish taken in 1928, we find that while all age groups taken in the two years grew at approximately the same rate in Muskellunge Lake (see also curves B and C, fig. 1), those taken from Trout Lake in 1927 grew much more rapidly than those secured in 1928 (curves A and D, fig. 1). The conflict in the data is thus obviously due to the marked difference in growth rates of the fish of the two collections from Trout Lake.

That this difference in the growth rates of the Trout Lake fish of the two collections is real, and not due to the inadequacy of the size of samples or of the method of sampling, seems probable from a comparison of the growth rates of age groups which belong to the same year class. Thus we may compare the growth rates of V–, VI– and VIII–year fish of 1927 with those of the VI–, VII– and VIII–year fish of 1928 (tables 3 and 4). The average calculated lengths in millimeters, at the end of each year of life, of the thirty V–year fish of 1927 are not shown in table 3; they are 23, 43, 66 and 99. The average measured length of the fish was 114 mm. The data show that in no instance did the growth rates of any two age groups of a year class agree; those of age groups taken in 1927 were consistently much greater than those of age groups taken in 1928.

The evidence seems to indicate that the two collections from Trout Lake represent separate populations or races, each with its own rate of growth, while both collections from Muskellunge Lake represent the same population. This conclusion agrees with the fact that in both years the Muskellunge Lake fish were taken in the same general locality (p. 583), whereas the two collections from Trout Lake were taken in two different localities (Blaisdell's Bay and Camp Franklin Shoal), separated by what appears to be a barrier to migration of the rock bass. For the reasons given in the introduction (p. 581), it is impossible, with the available information, to correlate this difference in growth rates with environmental factors.

The difference in age composition of collections from the two lakes (tables 1 and 2), as noted on p. 585, is partially explained on the basis of growth rates and selective action of gill nets. Most of the fish from the Trout Lake collection of 1927 fell in age groups V, VI, VII and VIII, while those from Muskellunge Lake of both years fell in age groups VI, VII, VIII and IX. This difference is explained by the more rapid growth of the 1927 Trout Lake fish; on the average, they would attain a greater length at any given age than would those from Muskellunge Lake and consequently more of the younger Trout Lake fish would be taken by the gill nets. The bulk of the collection of 1928 from Trout Lake fell in age groups VI, VII and VIII. The absence of V–year fish is to be expected from the fact that the fish of this collection grew more slowly than the 1927 fish and would thus have to grow for a longer period before reaching a size great enough to be selected by the gill nets. However, it may be due to the absence of V–year fish from the lake as suggested on p. 586. No explanation can be offered for the failure of the nets to take more IX– and X–year fish in 1928.

V. Summary

1. This paper is a preliminary report on the growth of the rock bass in Trout and Muskellunge Lakes, Vilas County, Wisconsin.

2. The growth curve of the rock bass typically has the form of a double sigmoid; that is, there are two periods of rapid growth, each followed by a decline.

3. The rate of growth in the second period of rapid growth is greater than that in the first. The first period usually occurs in the first year and the second in the fifth year. More individuals grow most rapidly in the fifth year of life than in any other; the second largest number grow most rapidly in the sixth year, and the third largest number in the fourth year.

4. Rock bass of collections from Muskellunge Lake made in 1927 and 1928 grew at approximately the same rate. The collections were made in the same general locality and are regarded as representing a single population.

5. Rock bass taken from Trout Lake in 1927 grew much more rapidly than those taken in 1928. The two collections were made in different localities and are regarded as representing two distinct populations, each with a characteristic rate of growth.

6. Trout Lake rock bass taken in 1927 grew more rapidly than those taken from Muskellunge Lake in the same year. Muskellunge Lake rock bass captured in 1928 grew more rapidly than those taken from Trout Lake in the same year.

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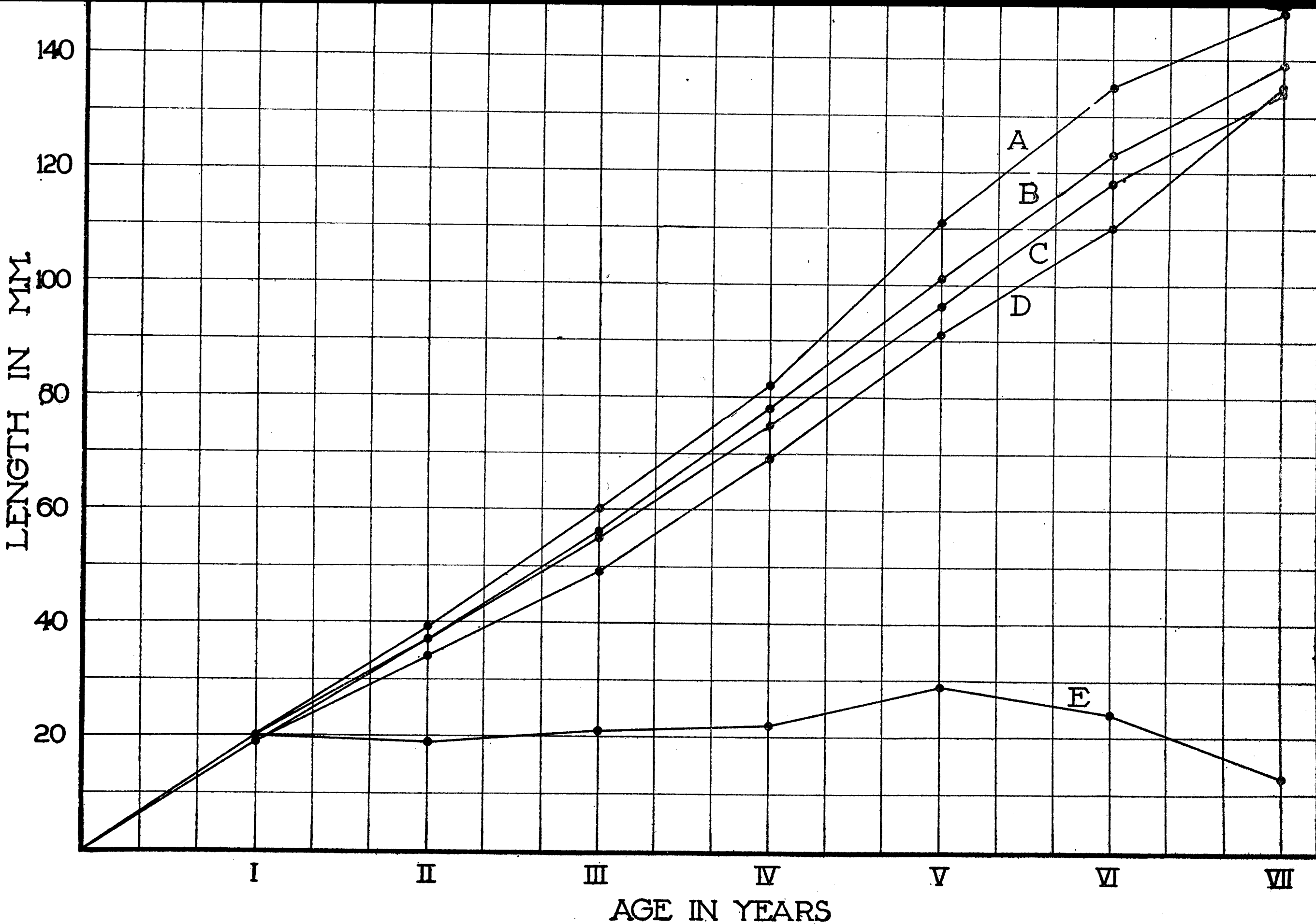

FIG. 1. Trout and Muskellunge lakes, 1927 and 1928. Average calculated length, at the end of each year of life, of rock bass of age groups VI, VII and VIII: A, Trout Lake 1927; B, Muskellunge Lake 1927; C, Muskellunge Lake 1928; D, Trout Lake 1928. E, annual growth increments taken from Curve A.

PROCEEDINGS OF THE ACADEMY

Fifty-seventh Annual Meeting, 1927

The fifty-seventh annual meeting of the Wisconsin Academy of Sciences, Arts and Letters, in joint session with the Wisconsin Archeological Society and the Midwest Museums Conference, was held at the University of Wisconsin, Madison, on Thursday, Friday and Saturday, April 7, 8 and 9, 1927.

The following program was presented:

THURSDAY, APRIL 7

Afternoon Session, 2:00 O'clock

Auditorium of State Historical Museum

Midwest Museums Conference.

1. Model Museum at the State Fair.
   a. What the Historical Department should contain. CHARLES E. BROWN.
   b. What the Natural History Department should contain. OWEN GRUMME, HURON H. SMITH, IRA EDWARDS and T. E. B. POPE.
   c. Methods of cataloguing, NILE BEHNCKE.
2. A course in museum work for midwest members. S. A. BARRETT.
3. Museum news exchange.
4. The museum specializing in some particular field. R. N. BUCKSTAFF.
5. A report on the recently formed Art Classes at the Oshkosh Public Museum. NILE BEHNCKE.

Business Meeting.

FRIDAY, APRIL 8

Morning Session, 9:00 O'clock

Auditorium of Biology Building.

General Meeting.

6. History of Costume. HAZEL MANNING. Illustrated.
7. The natural history department of a small museum. R. N. BUCKSTAFF.

8. Life and letters of Edward Lee Green. ANGIE K. MAIN.
9. The scope of botany. HURON H. SMITH. Illustrated.
10. A forty year old hobby. S. C. WADMOND.
11. Catalogue of the species of Hepaticae found in Wisconsin. GEORGE H. CONKLIN. By Title.
12. Notes on parasitic fungi in Wisconsin. XV. J. J. DAVIS. By Title.
13. The chemical composition of Chara from Green Lake, Wisconsin. H. A. SCHUETTE. By Title.
14. Structure and behavior of century-old cells. J. B. OVERTON.

Afternoon Session, 2:00 O'clock

15. The measurement of educational processes and products. M. V. O'SHEA.
16. The intellectual resemblance of twins. CURTIS MERRIMAN.
17. The life and customs of the Tarahumari Indians in the Sierra Madre Mountains. R. M. BAGG. Illustrated.
18. Colonial debtors and English creditors. CURTIS NETTELS.
19. Recent photographs of Mars. FRANK E. ROSS. Illustrated.

SATURDAY, APRIL 9

Morning Session, 9:00 O'clock

20. Commemorative postage stamps of the United States. F. M. K. FOSTER. Illustrated.
21. Fort Winnebago. W. C. ENGLISH.
22. The relation between Erasmus and Luther as shown in their correspondence. ERNST VOSS.
23. Organic content of the waters of small lakes. E. A. BIRGE.
24. Studies of the development and prevention of apple scab epidemics. G. W. KEITT.
25. Reconstruction in Japan. L. S. SMITH. Illustrated.

Report of Secretary, April 1, 1926 to March 31, 1927.

Membership	
Honorary Members	6
Life Members	15
Corresponding Members	20
Active Members	316
Total	357
Resigned	1
Dropped for nonpayment of dues	2
Deaths	2
Total	5

The following members died during the year:

Frederick Belding Power, March 26	1927
Addison Emery Verrill	1926
John Barber Parkinson, April 3	1927

The Secretary presented the following applications for membership. On motion he was unanimously instructed to cast the ballot in their favor:

H. R. Aldrich, Madison
Anselm M. Keefe, West Depere
Curtis Putnam Nettels, Madison
Frank E. Ross, Williams Bay
Otto Struve, Williams Bay
George Van Biesbroeck, Williams Bay
Ruth I. Walker, Madison
Stillman Wright, Madison
J. Sidney Hooton, Williams Bay

Officers elected April 9, 1927 for three years:

President, Samuel A. Barrett, Milwaukee
Vice-President, Sciences, Storrs B. Barrett, Williams Bay
Vice-President, Arts, Arnold Dresden, Madison
Vice-President, Letters, E. K. J. H. Voss, Madison
Secretary-Treasurer, Chancey Juday, Madison
Curator, C. E. Brown, Madison
Librarian, Walter M. Smith, Madison

The annual dinner was held at the University Club on Friday evening, April 8, 1927, attended by 47 members and guests. Following the dinner Dr. Joseph Schafer delivered an address entitled "On the Gold Trail, 1849".

CHANCEY JUDAY,
Secretary.

Report of Treasurer from April 1, 1926 to March 31, 1927.

Receipts

Balance in State Treasury April 1, 1926	$4,353.17
Receipts from dues	228.10
Received from sales of Transactions	7.85
Received for reprints	45.97
Received from Mrs. E. J. B. Schubring	50.00
Interest	1.00
Annual appropriation, July 1, 1926	1,500.00
	$6,186.09

Disbursements

Drafting for Mrs. Schubring's paper	$22.00
Telephone message	.40
Envelopes (University)	1.00
Postage	61.50
Annual allowance of Secretary	200.00
Printing	2,202.13
	$2,487.03
Balance in State Treasury April 1, 1927	$3,699.06

Securities and cash on hand April 1, 1927

City of Madison bonds	$2,900.00
Mortgage bonds on Chapman Block, Madison	400.00
Certificate of deposit	34.72
Cash	8.80
	$3,343.52

CHANCEY JUDAY,
Treasurer.

Audited and found correct.
GEORGE WAGNER,
R. N. BUCKSTAFF,
Auditors.

FIFTY-EIGHTH ANNUAL MEETING, 1928

The fifty-eighth annual meeting of the Wisconsin Academy of Sciences, Arts and Letters, in joint session with the Wisconsin Archeological Society and the Midwest Museums Conference, was held at Lawrence College, Appleton, on Friday and Saturday, April 6 and 7, 1928.

The following program was presented:

FRIDAY, APRIL 6

Morning Session, 9:30 O'clock

General Business.

Presentation of Papers.

1. Wisconsin's oldest families. N. C. FASSETT. Illustrated.
2. A call for amateur botanists. N. C. FASSETT.
3. Notes on the flora of Lake Wingra. JEANETT KENDALL.
4. Forestry in Wisconsin. HURON H. SMITH. Illustrated.

5. Flora of Wisconsin sand dunes. A. M. FULLER. Illustrated.
6. Botanical groups. HURON H. SMITH. Illustrated.
7. Visual methods and devices for museums and schools. JOHN B. MACHARG.
8. Discussion of Lawrence Vale Coleman's "Manual for the small museum." Leaders of the discussion, R. N. BUCKSTAFF, and S. A. BARRETT.
9. Notes on the chemical composition of some of the larger aquatic plants of Lake Mendota. III. Castalia and Najas. HENRY A. SCHUETTE and HUGO ALDER. By title.
10. A note on the chemical composition of Chara from Green Lake, Wisconsin. HENRY A. SCHUETTE and HUGO ALDER. By title.

Afternoon Session, 1:30 O'clock

Presentation of Papers.

11. Eskimo picture writing. GEORGE A. WEST. Illustrated.
12. Wisconsin Indians after the British conquest, 1761–1775. LOUISE P. KELLOGG. By title.
13. Family names of civilized Indians. VETAL WINN.
14. The pottery repository at Ann Arbor. CHARLES E. BROWN.
15. Sacred springs of the Poygan region. GEORGE OVERTON.
16. The Reedsburg cache of flint implements. MILTON K. HULBERT.
17. Two fluted stone implements. VETAL WINN.
18. Indian trade clasp knives from Lake Koshgonong. THEODORE T. BROWN.
19. Balance and psychology of museum work. GEORGE R. FOX.
20. Airplane photograph of a Kenosha County effigy mound. C. W. BEEMER.
21. Indian fishing camps of the Wolf River. FRANCIS S. DAYTON. By title.
22. An early Chicago immigration society. ALBERT O. BARTON.
23. Museum classification and storage methods. T. E. B. POPE. Illustrated.
24. Trail-side and outdoor museums. A discussion led by S. A. BARRETT and R. N. BUCKSTAFF.
25. Hawaii, the Paradise of the Pacific. S. A. BARRETT. Illustrated with moving pictures.

SATURDAY, APRIL 7

Morning Session, 9:00 O'clock

General Business.

Presentation of Papers.

26. The sexes of hybrid pigeons and doves. L. J. COLE.
27. The University bird banding station. GEORGE WAGNER.
28. The transmission of solar radiation by the waters of Wisconsin lakes. E. A. BIRGE.

29. Mineral content of the waters of the Great Lakes. L. A. YOUTZ.
30. Redetermination of the atomic weight of arsenic. L. A. YOUTZ.
31. Recent studies of the Wisconsin Cambrian. IRA EDWARDS.
32. Merestomes of the Wisconsin Cambrian. GILBERT O. RAASCH. Illustrated.
33. The origin of Crater Lake. IRA EDWARDS. Illustrated.
34. The Devonian section of Little Traverse Bay, Michigan. GILBERT O. RAASCH.
35. The red salmon of Karluk. GEORGE I. KEMMERER. Illustrated with moving pictures.
36. William Langland's "Piers the Plowman" and Johannes von Saaz's "Der Ackerman aus Böhmen." ERNST VOSS. By title.

Report of Secretary, April 1, 1927 to March 31, 1928.

Membership	
Honorary Members	6
Life Members	15
Corresponding Members	20
Active Members	288
Total	329
New Members not included above	5
Grand total	334
Membership losses during year	
Deceased	4
Resigned	1
Dropped for nonpayment of dues	28
Total	33

The following Members died during the year:

Frank Gaylord Hubbard, March 15, 1928
Victor Lenher, June 12, 1927
Maurice McKenna, August 23, 1927
Harry E. Cole, April 13, 1928.

The Secretary presented the following applications for membership. On motion he was unanimously instructed to cast the ballot in their favor.

Demetrio di Demetrio, Trieste, Italy
Marcel Elias, Liege, Belgium
Paul S. Henshaw, Madison

Stephen John Martin, Madison
Samuel B. Sklar, Minneapolis, Minnesota
Vladimir N. Rimsky-Korsakoff, Madison
Willis L. Tressler, Madison
Charles H. Skinner, Marquette University, Milwaukee
Charles D. Higgs, Fontana
E. E. Honey, Madison.

The Annual dinner was held at Brokaw Hall on Friday evening, April 6, and was attended by 45 individuals. After the dinner President Wriston delivered an address on the subject "Opportunities for scholarly work in the Department of State".

The following motion was carried unanimously:

That we extend a hearty vote of thinks to Lawrence College for its kindly hospitality, and to Professor Bagg for the complete and efficient manner in which he looked after the local arrangements for our meeting.

CHANCEY JUDAY,
Secretary.

Report of Treasurer, April 1, 1927 to March 31, 1928.

Receipts

Balance in State Treasury April 1, 1927	$3,699.06
Receipts from dues	243.00
Received from sales of Transactions	26.62
Received for reprints	32.31
Annual appropriation, July 1, 1927	1,500.00
Total	$5,500.99

Disbursements

Annual allowance of Secretary	$200.00
Postage	109.00
Printing	2,902.74
Shipping labels	12.35
Total	$3,224.09
Balance in State Treasury April 1, 1928	$2,276.90

Securities and cash on hand April 1, 1928

City of Madison bonds	$2,000.00
Mortgage bonds on Chapman block, Madison	400.00
Trust agreement (Cent. Wis. Trust Co.)	1,000.00
Certificate of deposit	58.50
Cash	40.47
Total	$3,458.97

CHANCEY JUDAY,
Treasurer.

Audited and found correct.
GEORGE WAGNER,
HURON H. SMITH,
Auditors.

FIFTY-NINTH ANNUAL MEETING, 1929

The fifty-ninth annual meeting of the Wisconsin Academy of Sciences, Arts and Letters, in joint session with the Wisconsin Archeological Society and the Midwest Museums Conference, was held at Yerkes Observatory, Williams Bay, on Friday and Saturday, April 12 and 13, 1929.

The following program was presented:

FRIDAY, APRIL 12

Morning Session, 10:00 O'Clock

General Business

Presentation of Papers

1. The Potawatomi Indians of Lake Geneva. PAUL B. JENKINS. Illustrated.
2. Wisconsin Indians during the American Revolution. LOUISE P. KELLOGG.
3. An Abraham Lincoln Indian Medal. THEODORE T. BROWN.
4. An ancient village site in Winnebago County. GEORGE OVERTON.
5. Native plants used by Quileute Indians of Washington. ALBERT B. REAGAN.
6. The Indian copper mines of Isle Royal. GEORGE A. WEST. Illustrated.
7. Swamp dwellers. GEORGE R. FOX.

Afternoon Session, 1:30 O'Clock

Presentation of Papers

8. Large telescopes. FRANK E. ROSS. Illustrated.
9. Founding of the Republican party. S. M. PEDRICK.
10. Some general observations on immigration. J. SCHAFER. Twenty minutes.
11. Excavation of Paleolithic deposits of Algeria. GEORGE L. COLLIE. Illustrated.
12. The Lions of Cochiti. JOHN B. MCHARG. Illustrated.
13. Diary of an immigrant gold seeker in California. ALBERT O. BARTON.
14. Pioneer mills of Rock County. MAY L. BAUCHLE.
15. Indian village sites of the Lower Rock River in Wisconsin. C. E. BROWN.
16. The conservation of our Wisconsin lakes and streams. O. W. SMITH.
17. Problems encountered in pathological investigations of prehistoric bone material. HERBERT W. KUHM, GEORGE ADAMI and ALTON K. FISHER. Illustrated.
18. Phases of museum extension work. The Ohio Valley. ROY S. CORWIN. Illustrated.
19. Fostering zoological collecting among younger people. W. E. DICKINSON.
20. Wisconsin herpetological notes. T. E. B. POPE. Illustrated.
21. New restoration of Stegosaurus and Allosaurus. IRA EDWARDS. Illustrated.

SATURDAY, APRIL 13

Morning Session, 9:00 O'Clock

General Business

Presentation of Papers

22. Extremes of heat and cold in Wisconsin. ERIC R. MILLER. Illustrated.
23. New facts regarding the Wisconsin Cambrian. IRA EWARDS.
24. New facts regarding the Wisconsin Devonian. GILBERT O. RAASCH.
25. A remarkable abnormality in cats. GEORGE WAGNER.
26. The status of the European starling in Wisconsin. GEORGE WAGNER.
27. Color inheritance in pigeon hybrids. LEON J. COLE. Illustrated.
28. Resting-spores of Entomophthora species found on Aphis spiraecola. E. M. GILBERT.
29. Observations on Protoachyla. JAMES A. LOUNSBURY. Illustrated.
30. Delayed germination of Nelumbo lutea. J. A. JONES.

31. Occurrence of ferns in Wisconsin. W. N. STILES. Illustrated.
32. Some ecological studies of the Missouri River bluffs. DAVID F. COSTELLO. Illustrated.
33. Newer biochemical aspects of cold resistance in wheat. W. E. TOTTINGHAM.
34. Botanizing Wisconsin's lost lake. N. C. FASSETT. Illustrated.
35. Phases of museum extension work. The Ozark region of Missouri and Arkansas. W. D. KLINE. Illustrated.
36. Plant research among the Winnebago Indians. HURON H. SMITH. Illustrated.
37. Notes on parasitic fungi of Wisconsin. XVI and XVII. J. J. DAVIS. By title.
38. Wordsworth, science, and poetry. ARTHUR BEATTY.
39. Plan for a small astronomical museum. R. N. BUCKSTAFF. Illustrated.

Report of Secretary, April 1, 1928 to March 31, 1929.

Membership	
Honorary Members	5
Life Members	14
Corresponding Members	17
Active Members	345
Total	381
Membership losses during year	
Deceased	5
Resigned	3
Dropped for nonpayment of dues	3
Total	11

The following Members died during the year:

Thomas Chrowder Chamberlin, November 15, 1928
John Merle Coulter, December 23, 1928
Linnaeus Wayland Dowling, September 16, 1928
George I. Kemmerer, November 18, 1928
Benjamin W. Snow, September 21, 1928
William H. Wright, May 3, 1929

The Secretary presented the following applications for membership.

On motion he was unanimously instructed to cast the ballot in their favor.

Walter M. Banfield, Madison
H. W. Beams, Madison
Ethelwynn R. Beckwith, Milwaukee
George C. Blakeslee, Williams Bay

Lester M. Blank, Madison
Newton Bobb, Ashland
H. C. Bradley, Madison
H. N. Calderwood, Madison
Ralph M. Caldwell, Madison
Mary R. Calvert, Williams Bay
Thomas C. Carter, Madison
John O'Neill Closs, Madison
Grace L. Clapp, Milwaukee
William Wheeler Coleman, South Milwaukee
Delmer C. Cooper, Madison
David F. Costello, Milwaukee
Hobart W. Cromwell, Madison
L. A. V. DeCleene, West Depere
John E. Dudley, Jr., Madison
B. M. Duggar, Madison
C. T. Elvey, Williams Bay
Henry Ericson, Milwaukee
R. I. Evans, Madison
J. R. Fanselow, Appleton
Edward A. Fitzpatrick, Milwaukee
J. B. Goldsmith, Madison
L. F. Graber, Madison
William H. Gunther, Sheboygan
J. M. Hamilton, Madison
J. M. Hansell, Madison
Edmund Heller, Milwaukee
C. A. Herrick, Madison
George Hilton, Oshkosh
Wm. Horlick, Jr., Racine
Mark H. Ingraham, Madison
Charles A. Jahr, Elkhorn
James Albert Jones, Fond du Lac
H. H. Ketcham, Madison
Ruth H. Lindsay, Nashotah
Elizabeth F. McCoy, Madison
S. M. McElvain, Madison
J. D. Mac Lean, Madison
Carol Y. Mason, Milwaukee
V. W. Meloche, Madison
Albertine E. Metzner, Plymouth
Edward L. Miloslavich, Milwaukee
George W. Moffitt, Williams Bay
Clarence W. Muehlberger, Madison
Beatrice I. Nevins, Madison
Helen T. Parsons, Madison
Ernest A. Petzke, Hixton
A. H. Poetker, Milwaukee

Louise Pollitz, Oshkosh
Maximilian Rakette, Frankfurt, Germany
Allan F. Reith, Milwaukee
W. D. Richtmann, Madison
Caryl Ripley, Williams Bay
Walter E. Rogers, Appleton
H. W. Rohde, Milwaukee
Fred. George Russell, Milwaukee
Elbert B. Ruth, Madison
David A. Schaefer, Lake Geneva
Erwin R. Schmidt, Madison
B. L. Schuster, Waupun
Joel Stebbins, Madison
Walter E. Sullivan, Madison
James H. Taylor, Madison
Robert Triebel, Beuthen, Germany
K. H. Tutunjian, Ripon
J. H. Van Vleck, Madison
Ralph M. Walters, Madison
Frederick L. Wellmann, Tela, Honduras
A. H. Wiebe, Fairport, Iowa
Edgar J. Witzeman, Madison

The annual dinner was held on Friday evening, April 12, at the Rose Lane Resort; it was attended by 90 members and guests. Following the dinner Professor Edwin B. Frost gave a very interesting address on "The Architecture of the Heavens". After the address, members and guests were given an opportunity to look through the 12 inch and the 40 inch telescopes.

At the business meeting on Saturday the following motion was unanimously adopted:

We extend to the Director and the Staff of the Yerkes Observatory our thanks and our deep appreciation of their kindly hospitality and thoughtful solicitude in making this meeting of the Academy so enjoyable a success.

CHANCEY JUDAY,
Secretary.

Report of Treasurer, April 1, 1928 to March 31, 1929.

Receipts

Balance in State Treasury April 1, 1928	$2,276.90
Receipts from dues	312.00
Received for publication of paper (Prof. Owen)	711.41
Received from sales of Transactions	107.18
Received from sales of reprints	15.65
Annual appropriation July 1, 1928	1,500.00
Total	$4,923.14

Disbursements

Advertising, circular letter and cards	$ 10.00
Postage	73.50
Salary of Secretary	200.00
Express	2.16
Printing	2,613.73
Total disbursements	$2,899.39
Balance in State Treasury April 1, 1929	$2,023.75

Securities and cash on hand April 1, 1929

City of Madison bonds	$2,000.00
Mortgage bonds on Chapman Block, Madison	400.00
Trust agreement (Cent. Wis. Trust Co.)	1,000.00
Bonds of Commonwealth Telephone Co.	200.00
Cash	16.23
	$3,616.23

CHANCEY JUDAY,
Secretary.

Audited and found correct.
R. N. BUCKSTAFF,
GEORGE WAGNER,
Auditors.

LIST OF OFFICERS AND MEMBERS

CORRECTED TO MAY 1, 1929

OFFICERS

President, SAMUEL A. BARRETT, Milwaukee.
Vice-President, Sciences, STORRS B. BARRETT, Williams Bay.
Vice-President, Arts, ARNOLD DRESDEN, Madison.
Vice-President, Letters, E. K. J. H. VOSS, Madison.
Secretary-Treasurer, CHANCEY JUDAY, Madison.
Curator, C. E. BROWN, Madison.
Librarian, WALTER M. SMITH, Madison.

COMMITTEE ON PUBLICATION

The President, ex-officio,
The Secretary, ex-officio,
W. E. Tottingham, Madison.

COUNCIL

The President, Vice-Presidents, Secretary, Treasurer, Librarian and Past Presidents retaining their residence in Wisconsin.

COMMITTEE ON LIBRARY

The Librarian, ex-officio,
W. H. BARBER, Ripon,
A. E. CULVER, Stevens Point,
GEORGE WAGNER, Madison.

COMMITTEE ON MEMBERSHIP

The Secretary, ex-officio,
P. W. BOUTWELL, Beloit,
R. N. BUCKSTAFF, Oshkosh,
HURON H. SMITH, Milwaukee.

PAST PRESIDENTS

HONORABLE JOHN W. HOYT,[1] 1870–1875.
DOCTOR P. R. HOY,[1] 1876–1878.
PRESIDENT A. L. CHAPIN,[1] 1879–1881.
PROFESSOR RONALD D. IRVING,[1] 1882–1884.
PROFESSOR THOMAS C. CHAMBERLIN,[1] 1885–1887.
PROFESSOR WILLIAM F. ALLEN,[1] 1888–1889.

[1] Deceased.

PROFESSOR EDWARD A. BIRGE, 1889–1890.
LIBRARIAN GEORGE W. PECKHAM,[1] 1891–1893.
PRESIDENT CHARLES R. VAN HISE,[1] 1894–1896.
PROFESSOR C. DWIGHT MARSH, 1897–1899.
PROFESSOR CHARLES S. SLICHTER, 1900–1902.
DOCTOR JOHN J. DAVIS, 1903–1905.
PROFESSOR LOUIS KAHLENBERG, 1906–1909.
PRESIDENT SAMUEL PLANTZ,[1] 1910–1912.
PROFESSOR DANA C. MUNRO, 1913–1915.
DIRECTOR HENRY L. WARD, 1916–1918.
PRESIDENT EDWARD A. BIRGE, 1919–1921.
PRESIDENT MELVIN A. BRANNON, 1922–1924.
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