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CHANCEY JUDAY,

Secretary.

CONTENTS

Page

The National Cost of the Inland Frontier, 1820–1830. CURTIS NETTELS ---------- 1

What Made Freneau the Father of American Prose? HARRY HAYDEN CLARK ---------- 39

Karnöffel, a German Card Game of the Sixteenth Century. ERNST VOSS ---------- 51

An Ordinance of the City of Frankfort of the Year 1597 Regulating Dresses, Marriages, Baptisms, etc. ERNST VOSS ---------- 57

The Diamond Mining Industry of South Africa. RUFUS MATHER BAGG ---------- 79

The Glover Bluff Structure, a Disturbed Area in the Paleozoics of Wisconsin. (With Plate 1.) GEORGE L. EKERN and F. T. THWAITES ---------- 89

The Varved Clay Deposit at Waupaca, Wisconsin. (With Plate 2.) E. W. ELLSWORTH and W. L. WILGUS ---- 99

The Composition of the Fat of the Silver Black Fox. H. A. SCHUETTE and RALPH W. THOMAS ---------- 113

Determination of Organic Phosphorus in Lake Waters. REX J. ROBINSON and GEORGE KEMMERER ---------- 117

The Determination of Kjeldahl Nitrogen in Natural Waters. REX J. ROBINSON and GEORGE KEMMERER-- 123

Determination of Silica in Mineral Waters. REX J. ROBINSON and GEORGE KEMMERER ---------- 129

Monthly Rainfall Maps of Wisconsin and Adjoining States. ERIC R. MILLER ---------- 135

The Plants of Some Northeastern Wisconsin Lakes. NORMAN C. FASSETT ---------- 157

Preliminary Reports on the Flora of Wisconsin. IV. Lycopodiaceae, Lycopodium. LEONARD R. WILSON--- 169

Page

Preliminary Reports on the Flora of Wisconsin. V. Coniferales. NORMAN C. FASSETT ---------- 177

Preliminary Reports on the Flora of Wisconsin. VI. Typhaceae, Sparganiaceae. NORMAN C. FASSETT ----- 183

Preliminary Reports on the Flora of Wisconsin. VII. Betulaceae. NORMAN C. FASSETT ---------- 189

Preliminary Reports on the Flora of Wisconsin. VIII. Aceraceae. NORMAN C. FASSETT ---------- 195

Preliminary Reports on the Flora of Wisconsin. IX. Elatinaceae—Waterwort Family. NORMAN C. FASSETT 199

Preliminary Reports on the Flora of Wisconsin. X. Haloragidaceae—Water Milfoil Family. NORMAN C. FASSETT ---------- 200

Preliminary Reports on the Flora of Wisconsin. XI. Ranunculaceae—Buttercup Family. LOIS ALMON--- 205

Investigations on the Nature of Protoachlya paradoxa Coker. JAMES A. LOUNSBURY ---------- 215

Physiological Studies in Relation to the Taxonomy of Monascus spp. (With Plates 3 and 4.) ELAINE M. YOUNG ---------- 227

The Water Mites of the Jordan Lake Region. (With Plates 5 and 6.) RUTH MARSHALL ---------- 245

The Hypodermal Glands of the Black Scale, Saissetia oleae (Bernard). II. The Ventral Glands. (With Plates 7–9.) WM. S. MARSHALL ---------- 255

Wisconsin Herpetological Notes. T. E. B. POPE------- 273

A Second Report on Solar Radiation and Inland Lakes. E. A. BIRGE and C. JUDAY ---------- 285

The Highland Lake District of Northeastern Wisconsin and the Trout Lake Limnological Laboratory. C. JUDAY and E. A. BIRGE ---------- 337

The Rotifer Fauna of Wisconsin. V. The Genera Euchlanis and Monommata. (With Plates 10–26.) FRANK J. MYERS ---------- 353

THE NATIONAL COST OF THE INLAND FRONTIER, 1820–1830

CURTIS NETTELS

On January 30, 1824, John Randolph of Roanoke, in a speech before the House of Representatives, unburdened his mind on the subject of federal aid to Western development. In the course of his remarks, he said: "What have we *not* done for the West? Do gentlemen want monuments? Unless the art of printing should be lost, posterity will find them in your statute books, and in the journals of this House. They may find them in Indian Treaties for the extinguishment of title to lands . . .; in laws granting every facility for the nominal payment—and, he might also say, for the spunging, of the debts due the Government, by purchasers of the public lands—in the grants, which cannot be found in the older States, for the establishment of schools, and for other great objects of public concernment, for which nothing has been given to the States of the East. In a word, they would find them in the millions which this nation has disbursed, and is now disbursing, for the acquisition of the navigation of the Mississippi, and for the purchase of Louisiana. If these be nothing . . . then indeed we have done nothing for the West."[1]

This complaint is symptomatic of the dissatisfaction of the Old South with the growth of the West and with the increasing cost of government in the United States. It implies a difference between the old states and the new in their relation to the federal system. Is there ground for such a distinction? Was it true, as Randolph intimated, that the West was bearing heavily upon the federal exchequer? At what expense was the new section held by the arm of the general government? These questions raise another question: What is meant by the West or the frontier in the decade of the twenties? What physical area did it cover, and why may such an area be regarded as a unified region, differentiated from the states of the East?

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[1] *Annals of Congress*, 18 Cong., 1 Sess., 1298–99.

In a general way, the frontier for the period 1820–1830 may be described as the region embracing the states of Ohio, Tennessee, Kentucky, Indiana, Illinois, Missouri, Mississippi, Alabama, and Louisiana, together with the three territories of Arkansas, Florida, and Michigan. If this area constituted in the twenties a unified section, it was not so because the ratio of population to territory was uniformly equal in all regions at all times. Factors and conditions other than an even distribution of population gave the section its unity during the period. These are worth a little consideration in advance.

All of these states, as states, were younger than the federal government. They differed from the old states in this respect:—the citizens of the old states had established the federal government after their own state governments had taken form, whereas the residents of the new states had set up their state institutions after the federal structure had been erected, and had appealed to Congress for admission of the new units into Union. The federal government was the product of the experience of the colonies and of the first states; the new state governments, on the other hand, were patterned after the federal establishment. Many of the new states suffered under legal disabilities from which the old states were exempt. The new members were unequal in at least three respects: they did not enjoy the full advantages of the federal court system; they could not tax a large part of the land within their borders; and they did not have jurisdiction over an important population element on their lands—the Indians.

The inequality and newness of the frontier state produced a condition peculiar to itself. They magnified the importance of the federal government. For two reasons. By contrast with it, the new states were weak and faltering, and their weakness served as a foil to set off the greatness of the national power. The state capitals on the frontier were often at first but clearings in the woods; state legislatures met in barns or log houses; and the income and finances of the governments were appallingly meagre, compared with the resources of the nation. In the second place, since the federal government had a jurisdiction over many frontier concerns which it did not hold over the old states, it was actually more of a supervising agency in regard to them than it was in respect to the original thirteen.

The newness of the frontier had yet another effect. During the years after the war, the West was peopled principally by settlers who came from the older states. Under normal conditions, taking up residence on the frontier meant that the newcomer acquired a somewhat national point of view. He lost his connection with his former state, but his affiliation with the nation remained unaffected. As a result of this condition, and because of the weakness of the new state governments, a presumption in favor of federal legislation—whenever it would benefit the new states—took a strong hold upon the western voter.

A third condition common to the frontier appeared in a marked uniformity of opinion on many of its problems of major importance. In respect to the transportation issue, the new states stood almost as a unit in favor of federal aid. On the details of internal improvement schemes, the West might divide, but on the general principle of federal power it was unity itself. As for the land question—the new states could and did stand together on Benton's plan for reducing the price, and hastening the disposal of the public acres.[2] The frontier as a whole might not agree on a systematic Indian policy, but it could agree on the policy of pushing the tribes off their preserves. The same unity appeared when the currency question was agitated. The cry for more money comes with a common accent from all parts of the frontier during these years. Many devices for remedying the evil were proposed, but on the general idea underneath, there was substantial agreement.

Here again frontier conditions heightened the importance of the federal government in the West, and of the West in federal legislation. The simplicity and uniformity of life throughout the Mississippi Valley often prepared its population for united political action. Such conditions revealed in a clear light the real effect of the acts of Congress. The frontier responded readily to proposals respecting land policy, Indian affairs, internal improvements, and the currency, because they were intelligible to the ordinary voter,—because they reached down and touched in an understandable way his fundamental interests.

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[2] The Western senators, May 7, 1830, voted 16–1 in favor of Benton's plan. *Register of the Debates of Congress,* 21 Cong., 1 Sess., 427.

One more feature of the West should have a part in a definition of the frontier—its attitude toward the future. Interest in the development of the country is a mark of the Western man in Congress. If he be from the fringe of settlement, his interest is in removing the Indians, opening the land, and attracting population; if from the region uniting the edge of the frontier with the East, his interest in trade and transportation inclines him to support the measures that are deemed necessary for developing the lands farther on.

In a study of the federal relations of the frontier, the new states must form the basis of the definition of that area, since the federal system is concerned, not with population, but with states. The underlying conditions of the Western states appear sufficiently similar to warrant regarding them as defining the frontier of the then federal Union, and to warrant also an inquiry into the national cost of the frontier on the basis of that definition.

Measured by population, the importance of the Western states grew considerably between 1810 and 1830. The census figures speak for themselves.

Year	*Total (millions)*	*Western*	*Percent in West*
1810	7.22	1.	14
1820	9.65	2.2	23
1830	12.86	3.7	28

These figures show that the population of the whole country advanced during the decade 1820–1830 to the extent of 33 percent, whereas the population of the West increased to the extent of 65 percent. For the decade 1810–1820, the West contributed 49 percent of the increase of the total population; for the decade 1820–1830, it contributed 46 percent. The Western states, having but 14 percent of the population in 1810, contributed very nearly as much to the growth of the country in the following twenty years as did the East, which possessed 86 percent of the total at the beginning of the period.[3]

Did these population changes affect the cost of the federal government, and if so, to what extent? Whatever the influence of the West, it is clear that the federal government was

[3] Senate Document No. 505, 23 Cong., 1 Sess., pp. 78, 82, 86, 90, 94, 98, 102, 106, 110, 114, 118, 122, 128.

expanding in the late twenties, and that, in many quarters, this expansion was not at all welcome. On February 5, 1828, Representative Rives of Virginia presented figures to the House which revealed that the cost of the government had been mounting since 1822. The figure for the latter year was about $9,800,000; by 1826 it had reached $13,000,000. These figures were contrasted by Mr. Rives with others stating the cost of the government in Jefferson's day—which amounted to approximately $3,700,000.[4] Representative Mitchell of Tennessee reported in 1828 that there were then 9338 civil and military office-holders in the country. He had, he declared, "witnessed a very strong desire to multiply offices, but no movement for reform".[5] Did the West have anything to do with the expansion? "It has pleased some of the Atlantic gentlemen," remarked Senator Noble of Indiana in February, 1827, "not long since, to say that the People of the West were extravagant in their demands upon Congress."[6]

The legislative branch of the government reveals at one point the effect of the growing West. The aggregate membership of the two houses, including territorial delegates, rose from 234 in 1820–21 to 264 in 1830. During this time, the combined Western delegation grew from 45 to 68. Thus, of the 30 members added to Congress throughout the decade, 23 in number, or 76 percent were contributed by the West.[7]

Naturally the addition of Western members augmented the expense of Congress. For the session 1820–1821, the appropriations totalled approximately $372,000; for 1825–1826 the amount rose to $749,000; for 1829–1830 it stood at $670,000. During these years, the percentage of Western members was

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[4] *Abridgement of the Debates of Congress* . . . (New York, 1857–61), IX, 750, 746.

[5] *Ibid.*, IX, 681.

[6] *Debates*, 19 Cong., 2 Sess., 371.

[7] The growth of the Western delegation was as follows:

	Senate		*House*		*Aggregate*		*Percent*
Year	*Total*	*West*	*Total*	*West*	*Total*	*West*	*Western*
1810–11	34	6	146	14	180	20	11
1815–16	36	8	186	27	222	35	15
1820–21	46	16	188	29	234	45	19
1829–30	48–	18	216	50	264	68	26

—*Annals*, 11 Cong., 3 Sess., 9, 381–82; *Idem*, 14 Cong., 1 Sess., 9, 373–74; Senate Document No. 505, 23 Cong., 1 Sess., 142–44; *Congressional Directory of the First Session of the Twenty First Congress*, (Washington, 1829–30), *passim*.

respectively 19, 26, and 26. Thus the cost of the West may be estimated roughly as follows:—1820–1821 at $70,800; 1825–1826 at $194,800—1829–1830 at $174,200. These figures underestimate rather than overestimate the importance of the West, inasmuch as travel allowances are considered as the same for each member of Congress. Actually the Western members drew larger sums than the Easterners, as the former obviously had more traveling to do.[8]

That the Western delegation affected the business of Congress appears in two striking ways. In the first place, the Westerners, year by year after 1821, secured a larger percentage of standing committee memberships. Thus, the Western senators in 1821 occupied 22 of the then total of 70 places, or 31 percent. In 1830, they held 39 places or 45 percent of the total of 85.[9] In the House, the new states in 1820–21 held 19

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[8] The cost of Congress, according to appropriations, year by year.

Year	*Total*	*Members from West*	*Western Expense*
1820–21	$372,816	19	$70,835
1821–22	247,471	20	49,494
1822–23	338,290	20	67,658
1823–24	791,597	26	205,805
1824–25	402,107	26	104,547
1825–26	749,265	26	194,808
1826–27	433,390	26	112,681
1827–28	578,003	26	115,680
1828–29	523,748	26	136,174
1829–30	670,050	26	174,213

—*U. S. Statutes at Large,* III, 628, 668, 721, 758; IV, 3, 11, 79, 85, 137, 142, 208, 246, 321, 337, 377.

[9] The Standing committees of the Senate:

Year	*Total Places*	*Places Held by Westerners*	*Percent of Western Places*
1820–21	70	22	31
1821–22	70	24	34
1822–23	70	25	35
1823–24	70	27	38
1824–25	70	27	38
1825–26	80	35	43
1826–27	80	34	42
1827–28	85	36	42
1828–29	85	39	45

—*Journal of the United States Senate,* 16 Cong., 2 Sess., 22; *Idem,* 17 Cong., 1 Sess., 27–28; *Idem,* 17 Cong., 2 Sess., 21; *Idem,* 18 Cong., 1 Sess., 28–29; *Idem,* 18 Cong., 2 Sess., 30; *Idem,* 19 Cong., 1 Sess., 32; *Idem,* 19 Cong., 2 Sess., 29–30; *Idem,* 20 Cong., 1 Sess., 28–29; *Idem,* 20 Cong., 2 Sess., 21–23; *Idem,* 21 Cong., 1 Sess., 23.

of the 84 places, or 22 percent; in 1828–1829, 32 out of 133 places, or 23 percent.[10] Western interests, in addition, brought about the creation of new standing committees. Between 1816 and 1828 the Senate added eight new committees to its former list of ten. Of these eight, four dealt with Western matters—public lands, private land claims, Indian affairs, and agriculture. The House added a committee on private land claims in 1816, one on agriculture in 1821, one on Indian affairs and one on military affairs in 1822, and one on the territories in 1826. The House also created yearly a special committee on roads and canals which was a standing committee in all but name. The membership of this committee during the twenties was always at least 60 percent Western.

A survey of the federal statutes enacted during the decade explains the second manner in which the frontier affected the work of Congress. The new states may be regarded as a special charge of the federal government, requiring its particular attention, despite the fact that the territorial days had passed. The task of isolating laws that pertain to the frontier is not a difficult one to perform. There are many subjects of purely a Western aspect. Such are all phases of territorial government, public land policy, admission of new states, Indian affairs; such are many phases of military and judicial affairs, and of internal improvements. When the statute books are combed in making the list of laws distinctly Western, the result is truly remarkable, and fortifies the view that Congress,

[10] The Standing committees of the House:

Year	*Total committee members*	*Western members*	*Percent of Western members*
1820–21	84	19	22
1821–22	91	20	21
1822–23	119	22	18
1823–24	119	26	21
1824–25	119	27	22
1825–26	119	28	23
1826–27	133	31	23
1827–28	133	32	24
1828–29	133	31	23

—*Journal of the House of Representatives,* 16 Cong., 2 Sess., 9; *Idem,* 17 Cong., 1 Sess., 9–10; *Idem,* 17 Cong., 2 Sess., 18–19; *Idem,* 18 Cong., 1 Sess., 23–24; *Idem,* 18 Cong., 2 Sess., 26; *Idem,* 19 Cong., 1 Sess., 28–29; *Idem,* 19 Cong., 2 Sess., 23; *Idem,* 20 Cong., 1 Sess., 25–26; *Idem,* 20 Cong., 2 Sess., 21–22.

in dealing with new states, had a jurisdiction and a responsibility that did not at all characterize its dealing with the old states. As one studies the statutes of the period, one finds that laws bearing exclusively upon the old states are rare indeed, but that such acts for the Western states are common occurrences. Thus, in 1822 45 percent of the federal statutes related to the West; in 1824, 54 percent; and in 1827, 49 percent. For the other years of the decade the figures range between 32 and 41 percent.[11]

If it should be objected that many laws pertaining to the West were of slight importance, the reply comes that scarcely a session passed in which a Western measure was not of foremost concern. A list of the debates that would include that on the Missouri Compromises, on the land question, on the Florida treaty, on the extension of the judiciary into the West, on internal improvements, and on Indian affairs cannot be regarded as unimpressive or unimportant.

Meanwhile, the judiciary was feeling the force of expansion that was enlarging Congress. Of a total of 21 district judges in 1815, only four served in the West. In 1830, the new states had nine of the then 28. New offices had been created for Indiana, Illinois, Missouri, Mississippi, and Alabama.[12]

Naturally, the newly created courts inflated the cost of the judiciary. According to a rough estimate—rough in that it understates the expense of the Western courts—the cost of

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[11] The part of the West in federal legislation:

Year	*Total acts passed*	*Western acts*	*Percent Western*
1820–21	37	11	29
1821–22	61	28	45
1822–23	68	27	39
1823–24	87	47	54
1824–25	49	16	32
1825–26	91	38	41
1826–27	55	27	49
1827–28	81	29	35
1828–29	45	17	38
1829–30	77	31	40

[12] Indiana, March 3, 1817; Mississippi, April 3, 1818; Illinois, March 3, 1819; Alabama, April 21, 1820; Missouri, March 16, 1822. *U. S. Statutes at Large*, II, 390–91, 414, 502–03, 564–65, 653.

justice on the frontier rose from $22,900 in 1821 to $67,900 in 1830, an increase of $45,000 or 196 percent.[13]

In the executive branch of the government, the war department felt most strongly the effect of the westward movement. The expansion of population up the rivers emptying into the Ohio, the Mississippi, and (to a slight extent) the Missouri, brought new contacts between the settlers and the Indian tribes. "The number and importance of the treaties which have been held with the Indians since the late war," wrote Secretary Calhoun in 1822, "the great increase of the annuities and extension of the frontier have tended very much to increase the disbursements of the Indian Department."[14]

The period under study opened with a discussion in official circles of the wisdom of attempting the civilization of the Indians. Presidents Madison[15] and Monroe,[16] Secretaries Crawford[17] and Calhoun[18] favored such an attempt. In line with their views, Congress passed an act, March 3, 1819, allowing an annual appropriation of $10,000 "for the purpose of providing against the further decline and final extinction of the Indian tribes".[19] The amount of this annual grant was not increased during the twenties. Yet the movement for civilization made some headway in other directions. Between 1822 and 1829, various Indian appropriation acts carried 22 items for schools,

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[13] The size and cost of the judiciary:

Year	*Total* judges*	*Western* judges*	*Pct. of judges in the West*	*Total approp. for courts*	*Pct. of approp. due to West*
1821	34	9	26	$88,150	$22,919
1822	35	10	28	112,150	31,402
1823	35	10	28	154,413	43,236
1824	35	10	28	149,500	41,860
1825	35	10	28	290,700	81,396
1826	35	10	28	240,350	67,298
1827	35	10	28	241,611	67,610
1828	35	10	28	241,100	67,508
1829	35	10	28	241,800	67,704
1830	35	10	28	242,673	67,948

*Includes both circuit judges and district judges.
—*U. S. Statutes at Large,* III, 632, 672, 762; IV, 15, 89, 146, 213, 252, 342, 380.

[14] *Annals,* 17 Cong., 1 Sess., 726.

[15] *Idem,* 14 Cong., 2 Sess., 13.

[16] James D. Richardson, *A Compilation of the Messages and Papers of the Presidents* (Washington, 1895–98), II, 46.

[17] Senate Document, 14 Cong., 1 Sess., pp. 4–7. *Report of the Secretary of War on Indian trade* (no number).

[18] *Annals,* 15 Cong., 2 Sess., 2461–62.

[19] *Ibid.,* 2527.

blacksmiths, mills, houses, farming implements, cattle and reservation lands—applying to twelve different tribes.[20] The total appropriated came to $213,800. Slight as was this beginning in teaching the Indians the art of farming and the elements of book learning, it is none the less important as the real starting point of a policy that was pregnant with the possibilities of future expense.

For the most part, Congress saw fit to deal with the Indians in an opportunistic spirit. The appropriations for civilizing the tribes were small compared with those which went for annuities and presents. In 1817, an impending need for such gifts from the great father was recognized by the acting-Secretary of War. He wrote in January to the House committee on ways and means, urging an enlarged appropriation for the Indian department. "The circumstanced limits of most of the Indian tribes east of the Mississippi and Illinois rivers," he said, "having rendered their dependence on the chase more precarious, has produced a more frequent intercourse between these Indians and the agents of the United States, and a consequent increase of the issue of rations and presents to them."[21]

Some annuities were permanent; others for periods ranging from six to twenty years. In 1820, the Government's obligation under this head amounted to $52,580. By 1828, the figure had reached $237,600. The total sum for which the United States was responsible, year by year, during the decade, reveals a widening application of the annuity policy.[22]

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[20] *Idem,* 17 Cong., 1 Sess., 2622–23; *Idem,* 18 Cong., 1 Sess., 3241, 3271; *Debates,* 19 Cong., 1 Sess., Appendix xxv, xxvi; *Idem,* 19 Cong., 2 Sess., Appendix, xviii; *Idem,* 20 Cong., 1 Sess., Appendix, xxxi, xiv; *Idem,* 20 Cong., 2 Sess., Appendix, 69.

[21] *Annals,* 17 Cong., 1 Sess., 726.

[22] Annuities for the Indian tribes:

Year	*Total appropriation*
1821	$152,730
1822	168,880
1823	168,880
1824	190,880
1825	190,880
1826	241,654
1827	237,154
1828	237,654
1829	233,654
1830	211,654

—Senate Document No. 1, 20 Cong., 2 Sess., p. 112; U. S. *Statutes at Large,* III, 690, 749; IV, 37, 181–82, 217–18, 232–33, 300–01, 361–62, 373, 390.

These annuities were authorized by treaties with the tribes. Such treaties entailed other expenses on the War department. The Indians had to be cared for during the treaty pow-wow. The treaties often arranged for some instruction of the tribes in the mechanical arts, granted presents of money or goods, and provided for the purchase of Indian lands, for the building of roads in reservations, for paying indemnities to sufferers from Indian depredations, and for the survey of special tracts in which the negotiating tribe was interested. According to War department estimates, the cost of these treaties rose from $118,000 in 1821 to $519,000 in 1825.[23]

When the executive branch of the government was organized in 1789, the management of Indian affairs was assigned to the Secretary of war. By 1815, the duties of that official had become so heavy, that Secretary Crawford, during his tenure of the war office, made vigorous exertions to have the care of the Indians transferred to a separate department.[24] His pleas brought no change. Meantime, the Indian personnel continued to grow. In 1818, there were 15 agencies for the tribes; between that year and 1830, 12 new ones were added.[26] The employes of the Indian service by 1826 numbered 85, earning, all together, a yearly salary of $58,600.[27]

Congress, in May, 1822, created the office of superintendent of Indian affairs, which agent was domiciled at St. Louis and given supervision of the trans-Mississippi tribes.[28] This act, however, did not solve the problem of the management of Indian affairs. In November, 1829, Superintendent Thomas L. McKenny reported to Congress that a re-organization of the Indian bureau was "indispensable to its efficiency". "It is . . . too powerless to be effective, and too responsible for its feebleness. . . . A new organization has been esteemed to be important by every head of the Department of War, including the one under whose administration it was created, and

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[23] Senate Document No. 63, 19 Cong., 2 Sess., pp. 8–9.

[24] *Idem,* 14 Cong., 1 Sess., pp. 5–6. *Report of the Secretary of War on Indian trade* (no number).

[25] *Annals,* 15 Cong., 1 Sess., 2583.

[26] *Idem,* 15 Cong., 2 Sess., 2524, 2530–31; *Idem,* 17 Cong., 2 Sess., 2612; *Idem,* 18 Cong., 1 Sess., 3220, 3228; *Debates,* 18 Cong., 2 Sess., Appendix, 105; *Idem,* 20 Cong., 1 Sess., Appendix, xiv.

[27] Senate Document No. 88, 19 Cong., 1 Sess., pp. 102–05.

[28] *Annals,* 17 Cong., 1 Sess., 2612.

recommended by them all."[29] Experts on Indian affairs drafted a plan for the desired re-organization which was given the seal of law in 1834. The new act relieved the governors of the territories of Florida and Arkansas of duties pertaining to Indian agents; the governor of Michigan Territory was to be relieved when a new territory was created west of Lake Michigan. Twelve agencies survived, but five of these were to be discontinued soon—at the close of either 1834 or 1836.[30] Inasmuch as the removal policy was now in force, fewer independent agencies were assumed to be needed; the work of the department might be performed by sub-agents working directly under the superintendent.

Thus the administration of Indian affairs was simplified while its cost to the government continued to rise. In 1825, Representative McDuffie stated that in peace times more money was spent on Indian affairs than on the navy.[31] An attempt made in 1820 to reduce the expense of the service had ended in failure, Secretary Calhoun writing in 1821 that "the expenses of the Department have been accumulating against the Government without the means of meeting them."[32] By 1832, the Government had 70,000 Indians under its care—a supervision which cost $1,352,419 for that year.[33]

The appropriations for Indian affairs advanced after 1820 at a respectable rate. The total for 1830, $1,072,000—as compared with that for 1820, $462,000—represents an increase of $610,000, 132 percent. The trend of expense after 1815 was steadily upward, indicating thereby possibilities for larger appropriations in the future.[34]

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[29] Senate Document No. 1, 21 Cong., 1 Sess., p. 167.
[30] *U. S. Statutes at Large,* IV, 735–38.
[31] *Debates,* 18 Cong., 2 Sess., 247.
[32] *Annals,* 17 Cong., 1 Sess., 726–27.
[33] Senate Document No. 55, 44 Cong., 1 Sess., p. 2.
[34] Appropriations for Indian affairs:

Year	*Total*	*Year*	*Total*
1811	$163,011	1825	$777,856
1820	462,030	1826	1,026,196
1821	520,745	1827	622,068
1822	482,625	1828	822,282
1823	389,380	1829	727,323
1824	552,805	1830	1,072,579

—Precise references to authorities cannot be given conveniently. The figures were compiled by thorough scanning of all appropriation acts, and separating the numerous items for Indian affairs.

The main thing about Indian relations of the twenties is the mounting cost due to annuities and treaties. Neither of these items was new to the appropriation lists. Yet they indicate an important change in Indian policy. The abandonment of the factory system in 1822 came as a result partly of pressure from the West.[35] That system was offensive to the Westerners, not so much because it meant a restriction of individual enterprise in pursuit of the fur trade, but because it rested on the idea that the Indians were to be allowed to keep their valuable hunting lands and to maintain themselves by the chase. The system came under fire soon after population began to press onto these lands in the Mississippi Valley. Its abandonment necessitated a new means of pacifying and caring for the Indians. Such a means was now afforded by making some of the tribes the wards of the government,—dependent for their subsistence on its care and bounty. The government changed its position from that of trade regulator to that of gift dispenser. No alteration in the character of the federal government accompanied this change. But the possibility of expense inherent in the new policy was considerably greater than in the policy which had preceded it.

When Representative McDuffie in 1825 estimated the cost of the Indians as equal to the cost of the navy, he doubtless included in his figure the expense of that part of the army kept on the frontier for its defense against the tribes. The army of the United States after the war of 1812 was not a large one. By the act of March 2, 1821, the legal force of officers and men was reduced from 10,000 to 6,000.[36] Here it stood throughout the twenties. The actual number of troops in service fell from 9200 in 1820 to 4700 in 1823. Then came a gradual increase, bringing the force to 5200 in 1830. Small as this force was, compared even with that of 1817, it was nearly twice as large as the army of Jefferson's day.

In justifying the increase that had taken place since 1802, Secretary Calhoun pointed out in 1818 that there were then 73

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[35] *U. S. Statutes at Large,* III, 679–80.
[34] *U. S. Statutes at Large,* III, 615–16.
[35] *Annals,* 16 Cong., 2 Sess., 791.
[36] Senate Document No. 1, 21 Cong., 1 Sess., p. 138.

frontier posts, as against 27 in the former year.[37] At the close of the period studied, the Quartermaster General, in reporting estimated expenditures for 1830, said, "It has been found necessary to increase the estimates of the Department for the ensuing year, under several heads of expenditure. The necessity . . . results from the extended operations and increased activity of our little army, occasioned by the extension of our frontiers, and the great increase of Indian force west of the Mississippi. The army being too small to occupy all the points that require protection, the Government is compelled to supply the want of numbers by frequent movements. It is believed that the necessity for movements will remain so long as our citizens continue to extend their settlements westward, and carry on a trade with the Indians, and the Mexican States. If the policy of the Government and the circumstances of the country remain unchanged, every cent will be required."[38]

During the twenties, a somewhat significant change occurred in the organization of the army. Prior to 1822 it consisted of two divisions—one of the North and one of the South. In 1821, the war department re-organized the service, abolishing the old divisions and establishing new ones: the Eastern and Western. Even before this change, a large part of the army operated on the frontier. The Western force reached its high point in 1822, when it consisted of 69 percent of the whole army. For the other years of the decade, the Western troops numbered between 56 and 66 percent of the total force.[39]

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[37] *Annals,* 16 Cong., 2 Sess., 791.

[38] Senate Document No. 1, 21 Cong., 1 Sess., p. 138.

[39] Distribution of the Army:

Year	*Troops in East*	*Troops in West*	*Pct Western*
1821	1959	3438	65
1822	1465	3354	69
1823	1798	2969	62
1824	1941	3210	62
1825	1884	3184	61
1826	1820	3622	66
1827	1897	3416	64
1828	2047	2686	56
1829	2230	3128	56
1830	1965	3213	62

—House Executive Document No. 92, 17 Cong., 1 Sess., p. 3; Senate Document No. 1, 17 Cong., 2 Sess., pp. 7–8; Senate Document No. 2, 18 Cong., 1 Sess.,

The national expenditure for military defenses falls under four heads. The most important of these covers the cost of maintaining the army in action—and includes charges for supplies, ammunition, arms, clothing, pay of officers and men, and transportation. A rough estimate of the military cost of the frontier may be made by comparing the total appropriations for the army with the number of troops stationed in the West. Such an estimate will err in placing the Western expense too low rather than too high. Transportation charges of course inflated the cost of the frontier forces. Very probably the Western troops saw more action, and consumed materials and supplies more rapidly than the Eastern. The total appropriation for maintaining the army in 1821 was $2,600,000. If 65 percent of the army was then in the West, at least $1,700,000 went for that section. After 1821, the cost of the frontier on this head ranged from $1,048,000 to $1,750,000.[40]

A second branch of the military expenditure relates to provision for arming the militia. An act of April 23, 1808 allowed an annual grant of $200,000 for this purpose.[41] The percentage of the militia in the West rose from 24 in 1821 to 29 in 1830. Hence during the decade the Western share of the ap-

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tables 4, 5; *Idem,* No. 1, 18 Cong., 2 Sess., p. 68; *Idem,* No. 1, 19 Cong., 1 Sess., p. 10. *Idem,* No. 1, 19 Cong., 2 Sess., p. 180; *Idem,* No. 1, 20 Cong., 1 Sess., p. 48; *Idem,* No. 1, 20 Cong., 2 Sess., pp. 31–33; *Idem,* No. 1, 21 Cong., 1 Sess., pp. 56–58; *Idem,* 21 Cong., 2 Sess., pp. 88–90.

[40] The cost of maintaining the army:

Year	*Total Approp.*	*Pct of Army in West*	*Approp. for West*
1821	2,639,974	65	$1,715,983
1822	2,200,660	69	1,518,455
1823	2,207,339	62	1,368,550
1824	2,215,204	62	1,373,426
1825	2,277,648	61	1,389,365
1826	2,389,894	66	1,577,330
1827	2,640,364	64	1,689,333
1828	3,125,467	56	1,750,261
1829	1,872,679	56	1,048,700
1830	2,464,581	56	1,528,040

—*U. S Statutes at Large,* III, 612, 633, 652–53, 686–87. 748–49; IV, 8–9, 36, 82–83, 150–51, 214–15, 257–59, 314, 348–50, 357, 374–75.

[41] *Ibid.,* II, 490.

propriation increased from $48,000 to $58,000.[42] In 1884 this act was still in force. The distribution of the appropriation at that time shows an expenditure of $120,000 for the new states, the old states having then but 40 percent of the total militia.[43]

One result of the war of 1812 took the form of a change in policy regarding coast defenses. Presidents Madison and Monroe, and Secretary Calhoun were the authors of this change, which aimed at the construction of permanent fortifications at strategic points along the maritime frontier. Calhoun wrote in 1818, "It has been determined by the War Department that the fortifications which may be hereafter constructed upon the Atlantic and Gulf of Mexico frontiers, shall be permanent works and of dimensions adequate to the defense of the positions or passes which they may occupy. . . ."[44]

In March, 1822, President Monroe pointed out the importance of the West in this program. "It is known that no part of our union is more exposed to invasion by the numerous avenues leading to it, or more defenseless by the thinness of the neighboring population, or offers a greater temptation to invasion, either as a permanent acquisition or as a prize to the cupidity of grasping invaders from the immense amount of produce deposited there, than the city of New Orleans. *It is known also that the seizure of no part of our Union could affect so deeply and vitally the immediate interests of so many states and of so*

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[42] Appropriation for arming the militia:

Year	*Percent of militia in West*	*Expenditure for West*
1821	24	$48,000
1822	26	52,000
1823	25	50,000
1824	25	50,000
1825	25	50,000
1826	27	54,000
1827	27	54,000
1828	28	56,000
1829	28	56,000
1830	29	58,000

—*Ibid., House Executive Document* No. 107, 16 Cong., 1 Sess., p. 8. *Idem,* No. 104, 16 Cong., 2 Sess., I; *Idem,* No. 91, 17 Cong., 1 Sess., p. 2; *Idem,* No. 108, 17 Cong., 2 Sess., II; *Idem,* No. 103, 18 Cong., 2 Sess., II; *Idem,* No. 93, 19 Cong., 1 Sess., p. 2; *Idem,* No. 130, 19 Cong., 2 Sess., p. 2. Senate Document No. 1, 20 Cong., 1 Sess., p. 126; House Executive Document No. 110, 20 Cong., 2 Sess., p. 2a; Senate Document No. 45, 21 Cong., 1 Sess., p. 4; House Executive Document No. 98, 22 Cong., 1 Sess., pp. 2–3.

[43] Senate Report No. 61, 48 Cong., 1 Sess., pp. 1–2.

[44] House Executive Document No. 56, 15 Cong., 2 Sess., pp .5–6.

many of our fellow citizens, comprising all that extensive territory and numerous population which are connected with and dependent on the Mississippi, as the seizure of that city. Strong works, well posted, were therefore deemed absolutely necessary for its protection."[45]

For the defense of the Gulf positions, Calhoun proposed the following system: (1) a fort at Barrataria, commanding the entrance into Barrataria bay, (2) one at Placquimine turn on the banks of the Mississippi, sixty miles below New Orleans, (3) one at Bayou Bienvenue, near Lake Borgne, and covering the approach to New Orleans through that lake, (4) and (5) one at Chef Menteur and one at Rigolets, on the margin of the passes into Lake Ponchartrain, to cover the approach to the rear of New Orleans and the country above, (6) and (7) at Mobile Point and Dauphin Island, for the control of the entrance into Mobile Bay.[46] When Florida was secured, Pensacola was added to the list.

The first appropriation came in 1821. During the twenties, a total sum of $6,684,000 was appropriated for all fortifications. Of this amount, $2,487,000, or 37 percent was to be expended for the Western defenses.[47]

The fourth branch of army expenditure includes the items for the construction of armories, arsenals and barracks. Shortly after the war, a proposal for building an armory on the Western waters attracted more than ordinary attention.[48] Congress in 1823 voted $5000 for preliminary investigations.[49]

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[45] Richardson, II, 119–20. Italics are mine.

[46] House Executive Document, No. 56, 15 Cong., 2 Sess., pp. 5–6.

[47] Appropriations for coast defenses:

Year	*Total*	*Western*
1821	$282,000	$90,000
1822	350,000	180,000
1823	474,000	190,000
1824	620,000	335,000
1825	874,621	338,000
1826	917,000	403,000
1827	500,000	106,000
1828	917,250	368,300
1829	793,393	164,447
1830	956,000	313,000

—*U. S. Statutes at Large,* III, 633–34, 686–87, 783–84; IV, 22, 92, 149, 216–17, 256, 310, 356–57, 374.

[48] House Executive Document No. 46, 19 Cong., 1 Sess., p. 12. *Ibid.,* No. 44, p. 3; House Committee Report No. 349, 23 Cong., 1 Sess., p. 6; Senate Document No. 18, 17 Cong., 2 Sess., p. 4.

[49] *U. S. Statutes at Large,* III, 788.

No funds to speak of were granted afterwards, and the project fell through. During the twenties, however, Congress appropriated $1,045,000 for the construction of arsenals and barracks. Of this sum, $356,225, or 34 percent went to the needs of the Western service.[50]

The total cost of the army rose from $3,196,000 in 1821 to $3,924,000 in 1830, the Western increase being from $1,897,000 to $2,013,275. For the whole decade, the amount appropriated came to $33,945,000, the West obtaining 54 percent, or $18,533,000.[51]

The population changes after the war also affected the land office. In the first place, the number of local offices increased from 34 in 1820 to 42 in 1830.[52] In the second place, the maintenance of these offices during the period cost the government a total of $984,531.[53] In the third place, appropriations to the

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[50] Appropriations for arsenals and barracks:

Year	*Total*	*Western*
1821	$75,000	35,000
1822	16,500	12,000
1823	62,578	29,178
1824	4,135	4,135
1825	52,600	12,000
1826	117,500	23,000
1827	101,752	36,000
1828	155,300	61,000
1829	159,777	59,677
1830	304,136	84,235

—*U. S. Statutes at Large*, III, 633, 686–87, 784, 748–49, IV, 36, 83, 151, 179–80, 217, 241, 304, 355–56, 424–25.

[51] Total appropriations for the army:

Year	*Total*	*Western*
1821	$3,196,974	$1,897,983
1822	2,779,534	1,765,672
1823	2,968,977	1,647,728
1824	3,039,339	1,762,561
1825	3,404,869	1,789,365
1826	3,684,385	2,117,321
1827	3,481,376	1,934,593
1828	4,438,017	2,275,561
1829	3,026,905	1,329,680
1830	3,924,917	2,013,275

[52] House Executive Document No. 66, 23 Cong., 2 Sess., pp. 3–4.

[53] Cost of local land offices:

Year	*Total*	*Year*	*Total*
1821	$82,573	1826	$113,212
1822	85,930	1827	121,281
1823	61,668	1828	95,765
1824	105,051	1829	109,351
1825	114,893	1830	94,807

—House Executive Document No. 170, 19 Cong. 1 Sess., *passim; Idem*, No. 94, 17 Cong., 1 Sess., p. 4; *Idem*, No. 16, 18 Cong., 1 Sess., p. 18; Senate Document,

amount of $135,544 were granted for adjusting land claims in the Western country.[54] And finally, an additional sum of $1,047,000 was set aside for surveying the public lands.[55]

The appropriations for surveys show a falling off during the Adams administration. This decrease, however, tells but half the story. In 1833, Commissioner Hayward called the attention of Congress to "the absolute necessity of providing increased means for the surveyors' offices." For some years past, he said, it had been "*matter of notoriety* in the several surveying districts (of which there are now seven) that the government has failed to accomplish the object of the laws of Congress in having lands brought into market after the surveys have been made, for want of force in the surveyors' offices, by reason of the inadequacy of the appropriation. The public interest and that of individuals, equally demand that those surveys be brought into market. Depredations are constantly being committed on the timber, thereby depreciating in numerous instances, the value of the land." "There are," he added, "about 400 townships of land surveyed, which cannot

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No. 3, 19 Cong., 2 Sess., D; *Idem,* No. 1, 20 Cong., 1 Sess., p. 265; *Idem,* No. 1, 20 Cong., 2 Sess., p. 186; *Idem,* No. 1, 21 Cong., 1 Sess., p. 320; *Idem,* No. 1, 21 Cong., 2 Sess., p. 69; House Executive Document No. 3, 22 Cong., 1 Sess., p. 46; *Idem,* No. 160, 22 Cong., 2 Sess., pp. 3–6; *Idem,* No. 66, 23 Cong., 2 Sess., p. 6.

[54] Appropriations for adjusting land claims:

Year	*Total*	*Year*	*Total*
1823	$9,890	1827	$13,000
1824	14,500	1829	21,366
1826	3,773	1830	73,015

—*U. S. Statutes at Large,* III, 762; IV, 17, 147–48, 202, 239, 343–44, 381–82, 405.

[55] Appropriations for land surveys:

Year	*Total*
1821	$165,300
1822	113,300
1823	215,300
1824	106,700
1825	135,982
1826	93,431
1827	39,300
1828	52,300
1829	112,350
1830	13,300

—*U. S. Statutes at Large,* III, 631–32, 671–72, 761, 763; IV, 14–15, 16, 40, 65, 88–89, 90, 146–47, 212, 251, 341, 343, 379–80, 381.

be brought into market for want of more clerks and draughtsmen." His estimate of expenditures for 1833 called for an appropriation of $249,000 for certain expenses and of $110,000 for probable expenses—a total of nearly $360,000.[56]

As early as 1823, the Chairman of the House committee on public lands complained of confusion and congestion in the work of the General land office.[57] In 1827, the number of clerks in its employ was reduced from 24 to 18, on the assumption that the land operations of the government would become restricted in the future. This assumption proved erroneous. By 1830, the Department found itself in a straitened condition. Commissioner Hayward reported then to this effect: "Since that time [1827] the business of the office has greatly increased and accumulated until, with its diminished assistance, its arrears have become a serious impediment to the facilities of its operation. . . . The numerous legislative enactments in relation to the public lands, and to private claims thereto, since the year 1820, and especially the several relief laws . . . have required for their execution an annual amount of labor in this office equal to that of any previous year since its first organization."[58] So badly in arrears was the business of the department, that Commissioner Hayward believed ten additional clerks working full time would be needed during the coming two years in order to bring it up-to-date.[59]

Congress moved in 1836 for eliminating the defects in the land administration. The reorganization then effected provided for a commissioner of the General land office, two principal clerks to the commissioner, a principal clerk of surveys, a recorder of patents, a solicitor of claims, and a secretary to the commission. The minor personnel of the office was to consist of 83 clerks and draftsmen.[60] This act was the outcome of the earlier attempt to cut down the cost of the General land office. During the twenties, however, the expansion of the department had been prevented. The total appropriation for the

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[56] House Executive Document No. 46, 22 Cong., 2 Sess., pp. 2–3.
[57] *Annals,* 18 Cong., 1 Sess., 891–92.
[58] Senate Document No. 1, 21 Cong., 2 Sess., pp. 60–61.
[59] *Idem,* No. 1, 21 Cong., 1 Sess., p. 63.
[60] *U. S. Statutes at Large,* V, 109–12.

central administration during the decade amounted to only $254,300.[61]

When the various items for local agencies, surveys, claims, and central administration are brought together, they show a total appropriation of $2,421,638 for the ten years under consideration.[62] The money was obviously devoted to purposes 100 percent Western in character.

The cost of governing the territories was likewise a frontier item. The appropriations under this head advanced from $13,900 in 1821, to $63,919 in 1830, an increase of 384 percent. All items granted during the decade amounted to $399,238.[63]

The appropriations for navigation and inland transportation improvement are easily separated into Eastern and Western items, as the statute always designates the place in which a given work is to be constructed. At the beginning of the twenties, the total appropriation for these purposes came to $131,000. The Western share amounted to but $5,000 or 4 percent of the total. In 1829 the respective amounts were

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[61] Appropriations for General land office:

Year	*Total*	*Year*	*Total*	*Year*	*Total*
1821	$25,910	1824	$32,550	1827	$19,450
1822	26,250	1825	26,600	1828	23,450
1823	26,490	1826	26,600	1829	23,500
				1830	23,500

—*U. S. Statutes at Large,* III, 630, 670, 759; IV, 3, 87, 144, 210, 249, 325, 378.

[62] Total appropriations for the public lands:

Year	*Total*	*Year*	*Total*
1821	$273,783	1826	$237,026
1822	225,480	1827	193,031
1823	313,348	1828	171,515
1824	258,801	1829	266,567
1825	277,475	1830	204,622

[63] Total appropriations for territorial government:

Year	*Total*
1821	$13,900
1822	13,900
1823	37,735
1824	31,978
1825	34,732
1826	52,175
1827	37,846
1828	56,868
1829	65,185
1830	63,919

—*U. S. Statutes at Large,* III, 631–32, 672, 761–62; IV, 15, 89, 146, 212–13, 252, 328, 380.

$1,026,000 and $585,000, the Western portion being more than 50 percent. The appropriation for the West in 1829 was more than three and a half times the entire appropriation for 1821. Throughout the decade, the total sum granted equalled $5,653,000, of which 44 percent or $2,495,000 went for the benefit of the Western states.[64]

By the acquisition of Florida, February 19, 1821, the United States not only contracted to pay claims to the amount of $5,000,000, but also greatly enlarged its oceanic boundary. As a result, the inland frontier of the country acquired an extensive coastline—reaching now from the Sabine river to the southern part of Georgia—a stretch nearly as long as the coastline of the older Atlantic settlements. The trade of the interior, drawn together at New Orleans, and seeking its outlet around Florida, gave this section of the maritime frontier a yearly increasing importance, and made a perceptible impression on the naval policies of the federal government.

At the close of the war, Congress adopted a program for the gradual improvement of the navy. From 1821 to 1830, an annual appropriation of $500,000 for this purpose was in force.[65] In addition, five separate grants totalling $1,272,350 were authorized between 1821 and 1828 for procuring vessels to combat piracy in the Gulf of Mexico.

Piracy in the waters through which passed the trade of the West presented one of the main difficulties that confronted the navy during the fifteen years after the war. In the contest

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[64] Appropriations for internal improvements, etc.:

Year	*Total*	*Western*	*Percent Western*
1821	$131,291	$5,000	04
1822	162,428	15,750	09
1823	333,361	46,920	14
1824	389,633	197,500	51
1825	400,814	223,460	55
1826	727,354	307,479	41
1827	526,059	341,773	65
1828	1,196,298	382,230	32
1829	1,026,850	585,363	57
1830	779,433	379,805	48

—*U. S. Statutes at Large,* III, 632, 643–44, 672, 698–99, 728–29, 762, 780–81; IV, 5–6, 15–16–22, 32, 38, 48, 61, 71, 83, 90, 94, 100, 101, 124, 128, 132, 133–34, 135, 139, 147, 151, 162, 169, 170–71, 175–76, 213, 214–15, 227, 228–29, 230–31, 241–42, 244, 253, 275, 282–83, 290, 303, 329, 343, 345–46, 348–50, 351, 353, 363, 381, 394–95, 427–28.

[65] *Ibid.*, III, 642; IV, 242–43.

between Spain and her revolted colonies, the Spanish commander, General Morales, blockaded 1200 miles of the coast of the Spanish Main and interdicted all foreign commerce therein as contrary to the laws of the mother country. This order, declared a report of the House committee on foreign relations, January 31, 1825, had "been the fruitful source of most of the evils since suffered by all commercial nations in the West Indies and in the Gulf of Mexico. Numerous pirates and swarms of privateersmen, (subsequently degenerated into pirates)" had "preyed upon all neutral commerce."[66] Of the danger of this piracy to the Gulf states, Senator Johnson of Louisiana said in 1822: "The Gulf of Mexico . . . had, for a series of years, been infested by a horde of pirates, who had captured a great number of our vessels, and murdered the crews of many of them in the most shocking manner. The depredations of those freet-booters had not been confined to the sea; they had also engaged in smuggling goods, and introducing negroes into the State of Louisiana, in violation of the laws of the United States, and have even been so daring in their atrocities as to commit violence in the interior of the country, and to carry off the property of the inhabitants. These evils had prevailed to an alarming extent, and called for the most prompt measures to arrest them."[67]

The interest of the West in suppressing this piracy is not hard to comprehend. Representative Cook of Illinois described it in 1825 in this manner: "The Western country knows and feels that it is dependent for its prosperity, to a very great extent, on the owners of our shipping. It is through them that the trade of the interior gets an outlet to the ocean, and it has experienced the vast advantage which has been conferred by the navy on the security and advancement of the commerce of the country. The West has an extensive interest in enjoying a market for its product. In the state of the country, the only market for a very large portion of the interior is found at New Orleans; and the Western States have, therefore, a direct concern in the protection of the trade in the Gulf of Mexico."[68]

An act of March 3, 1819, delivered the first blow in the war on piracy. This act authorized the President to use as many

[66] *Debates,* 18 Cong., 2 Sess., Appendix, 49.
[67] *Annals,* 17 Cong., 1 Sess., 151–52.
[68] *Debates,* 18 Cong., 2 Sess., 733.

public armed vessels as necessary to protect American shipping.[69] Senator Johnson in the session of 1819–1820 tried to get more ships added to the navy for special service against the pirates in the Gulf.[70] An act of May 15, 1820 appropriated $60,000 for small vessels, not more than five, which could be used in shallow water.[71] Senator Johnson continued his labors during the session of 1821–1822. At this time, the House committee on foreign affairs reported favorably on the plan. "The Committee," ran the report," are also of opinion, that, extended as the American coast has now become, the danger of smuggling has considerably increased, and that both these considerations [i. e. piracy and smuggling] recommend the employment of an ample force, which, by scouring those seas, shall have the effect of driving the present free-booters from the ocean. . . ."[72]

President Monroe in December 1822 advised the organization of a special force adapted for pursuing the pirates into shallow waters.[73] Congress acted on the recommendation, and before the end of that year voted $160,000 for the desired force.[74] So persistent were the pirates that stronger measures were needed. In December, 1824, the President reported that the pirates were still molesting American trade, and urged further action.[75] A bill was introduced in response to this appeal. When enacted into law, it appropriated $500,000 for building ten sloops of war. This act also discontinued the naval service on Lakes Erie, Ontario, and Champlain.[76]

The appropriation thus authorized did not prove large enough to cover the cost of constructing the designated ships. Consequently, Congress allowed a second grant of $350,000 in March, 1826,[77] and a third grant of $201,350 in 1928.[78] The total appropriation for building sloops of war against piracy thus reached the figure of $1,051,350.

During the debates on the bill of 1825, Representative Ross

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[69] *Annals,* 15 Cong., 2 Sess., 2523.
[70] *Idem,* 17 Cong., 1 Sess., 151.
[71] *Idem,* 16 Cong., 1 Sess., 2239, 2614.
[72] *Annals,* 17 Cong., 1 Sess., 173.
[73] *Idem,* 17 Cong., 2 Sess., 249.
[74] *Ibid.,* 1337.
[75] *Debates,* 18 Cong., 2 Sess., Appendix, 6.
[76] *Ibid.,* Appendix, 117.
[77] *Idem,* 19 Cong., 1 Sess., Appendix, xix.
[78] Senate Document No. 2, 21 Cong., 1 Sess., p. 250.

of Ohio referred to estimates of the navy department to the effect that the operation and upkeep of these ten sloops of war would cost about $610,000 a year.[79] In each of the three years, 1826, 1828, and 1830, Congress augmented the regular Naval Appropriation Act by a supplementary act, making provision for the maintenance of the new piracy force.[80] These measures proved sufficient unto the need. In December, 1826, President Adams announced that the pirates had been "totally suppressed,[81] and thereafter the officials of the navy reported annually that they had the situation in hand.[82]

One result of the war on piracy was the establishment of a naval yard at Pensacola. In November, 1823, Commodore Porter advised that a naval depot be constructed there, "as a proper security for our commerce, and the permanent union of the States."[83] By an act of March 3, 1825, Congress appropriated $100,000 for the Pensacola yard,[84] the purpose of which, in the words of John Rodgers, a captain in the naval service against the pirates, was to provide "security and protection of the immense amount of commercial products to which the Ohio, the Mississippi, the Missouri, and their almost numberless tributary streams are continually giving vent."[85] Secretary Southard in December 1826 reported that the work had been undertaken and that the appropriation of $100,000 would not cover all the costs, "as the erection of works in that portion of the Union is very expensive."[86] By the construction of this station, the land frontier obtained one of the major naval yards on the coast. In 1828, there were seven of these in all—at Portsmouth, Brooklyn, Philadelphia, Washington, Norfolk, Boston, and Pensacola.[87]

The expansion of the United States in territory, commerce, and population brought to the navy a new task, not only in the Gulf of Mexico, but also in the Pacific. In 1824, President Monroe called attention to the growing trade interests of the

[79] *Debates,* 18 Cong., 2 Sess., 733.
[80] *U. S. Statutes at Large,* IV, 152, 311–12, 371.
[81] Senate Document No. 1, 19 Cong., 2 Sess., p. 15.
[82] House Executive Document No. 2, 20 Cong., 1 Sess., p. 199; Senate Document No. 1, 20 Cong., 1 Sess., p. 134; *Idem,* No. 1, 21 Cong., 1 Sess., p. 34.
[83] *Idem,* No. 1, 18 Cong., 1 Sess., pp. 197–98.
[84] *Debates,* 19 Cong., 2 Sess., Appendix, 1580.
[85] Senate Document No. 2, 21 Cong., 1 Sess., p. 232.
[86] *Idem,* No. 2, 19 Cong., 2 Sess., p. 8.
[87] *Debates,* 21 Cong., 1 Sess., Appendix, 32.

United States with the Northwest coast and recommended that a frigate be sent to explore the coast near the Columbia, preparatory to establishing a naval-military base on the Pacific.[88] Secretary of the Navy Southard wrote in the same year: "Our commerce . . . has increased so rapidly there, and is scattered over so large a space, that an addition of one or more vessels would be made, if that were within the control of the Department." "This addition," he continued, "will become indispensable, should the Government be disposed to make permanent provision for the protection of our commerce, and other interests in the neighborhood of the Columbia river, and on the Northwest coast. Constant experience shows the importance of such augmentation of the number of our vessels as will enable the Government to add to the force in the Atlantic and Pacific. Inconveniences are felt, and losses are sustained by our citizens, which might be prevented, were the means of their protection enlarged."[89] In 1827, Secretary Southard reverted to the subject: "Our trade on the Northwest coast—our extensive whale fishery, all demand the vigilance of Government—and the Government, duly estimating the interests of the country, have wisely stationed a portion of our Navy in that ocean, to protect our property and preserve our rights."[90] In 1823, the Pacific squadron consisted of two vessels carrying 56 guns; in 1826, of five vessels carrying 136 guns; in 1829, of four vessels carrying 92 guns.[91]

The appropriations for the navy cannot of course be separated into Eastern and Western items. Even in the case of the Gulf piracy, where Western interests were so conspicuously concerned, other elements than frontier trade entered—such as the seaboard trade with the West Indies, with Central America, and with South America. There is no way of telling how much of the increased cost of navy maintenance after 1821 was entailed by the expansion of the country westward. But there is no doubt that the growth of the Mississippi Valley trade and the rising interest in the far West did contribute to the enlarged appropriations for naval affairs. A modest esti-

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[88] *Idem*, 18 Cong., 2 Sess., Appendix, 7.
[89] Senate Document No. 1, 18 Cong., 2 Sess., p. 112.
[90] House Reports No. 56, 19 Cong., 2 Sess., p. 1.
[91] Senate Document No. 1, 18 Cong., 1 Sess., pp. 116–17; *Idem*, No. 2, 19 Cong., 2 Sess., pp. 10–11; *Idem*, No. 1, 21 Cong., 1 Sess., p. 222.

mate of frontier influence would include at least the $100,000 for the Pensacola yard, and the $1,272,350 granted for the war on piracy. During the late twenties occurred the first increase in the naval force of the Pacific. This was but the beginning of a development by which the expansion of the country ultimately enlarged the navy far beyond the expectations of the Jeffersonian democrats.

An analysis of appropriations between 1815 and 1830 reveals the failure of an attempt to reduce naval operations and costs. The effort succeeded until about 1823. The total amount granted fell from $3,954,000 in 1816 to $2,700,000 in 1821. Then followed a steady rise until the sum of $4,287,000 was reached in 1830. For this failure to keep operating costs down during the twenties, the activities of the Gulf pirates, and national interests in the Oregon country were largely responsible.[92]

The striking thing about the Post Office during the period discussed was its phenomenal expansion. President Adams reported in his second annual message that the increase of postal revenues during the three preceding years exceeded the total amount of receipts in 1801.[93] The gross postages paid rose from $1,029,000 in 1821 to $1,850,000 in 1830.[94] The number of clerks engaged in the Department at Washington advanced from 21 in 1816 to 45 in 1830.[95] The aggregate number of all

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[92] Appropriations for the navy:

Year	*Maintenance*	*Gradual improvement*	*War on piracy*
1816	$2,954,911	$1,000,000	
1820	2,992,035	1,000,000	
1821	2,209,092	500,000	$60,000
1822	2,216,733	500,000	
1823	2,333,019	500,000	160,000
1824	2,523,663	500,000	
1825	2,654,787	500,000	500,000
1826	2,737,880	500,000	350,000
1827	3,205,746	500,000	
1828	3,914,400	500,000	201,350
1829	2,591,686	500,000	
1830	3,787,361	500,000	

—*U. S. Statutes at Large,* III, 634–35, 642, 650–51, 676–77, 720, 763–64; IV, 20, 83, 127, 131, 140, 152, 170, 206, 242, 254, 304 311, 343, 360, 370, 371, 375.

[93] Senate Document No. 1, 19 Cong., 2 Sess., p. 15.

[94] House Executive Document No. 140, 15 Cong., 2 Sess., pp. 10–11; *Idem,* No. 76, 17 Cong., 1 Sess., p. 3; Idem, No. 95, 18 Cong., 1 Sess., p. 118; Senate Document No. 21 Cong., 2 Sess., p. 51.

[95] House Document, Letter of Secretary of Treasury on estimated expenditures for 1816 (no number), p. 22; *Idem,* No. 97, 21 Cong., 2 Sess., pp. 1–3.

persons engaged in the work of the service for 1825 was stated to be somewhere between 15,000 and 20,000. In 1828, the figure had leaped to 26,956.[96] So also the number of local post offices increased during the decade—from 4976 in 1821 to 8004 in 1829. In 1829, there were about 2006 post offices in the Mississippi Valley—more than the total number in the whole country in 1807, and more than twice as many as in 1800.[97]

The cost of the service mounted from $1,165,000 in 1821, to $1,933,000 in 1830.[98] Obviously the West contributed to this growth. In 1829, Postmaster General Barry, in referring to renewals of contracts made in that year, for the states of Indiana, Illinois, Missouri, Tennessee, Alabama, Mississippi, and the Territory of Arkansas, remarked, "The rapid increase of population in these sections of country, required considerable improvements in the frequency, the celerity, and the mode of transporting the mail on the leading routes, for which provision has been made in the renewal of contracts."[99] In November, 1830, the same Secretary reported that in many states "improvements in mail facilities have been loudly called for; and in many instances, the growing population and extending settlements of the country have absolutely required them."[100] During the year 1833, the entire mail service cost $2,033,000—and of this sum, $641,000, or 31 percent, was spent on the routes in the three territories and the nine Western states. This figure is larger than the total amount expended on the

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[96] Senate Document, No. 2, 19 Cong., 1 Sess., p. 168; *Idem,* No. 1, 20 Cong., 2 Sess., p. 180.

[97] House Executive Document No. 40, 15 Cong., 2 Sess., p. 11; Senate Document No. 1, 20 Cong., 2 Sess., p. 179; House Executive Document No. 76, 17 Cong., 1 Sess., p. 3; *Idem,* No. 7, 17 Cong., 2 Sess., p. 5; Senate Document No. 1, 20 Cong., 1 Sess., p. 259; *Idem,* No. 1, 21 Cong., 1 Sess., p. 43; House Executive Document No. 119, 21 Cong., 2 Sess., pp. 64–88.

[98] The estimates for the Post Office differ from those presented for the other branches of the Government in that the former represent actual expenditures; the latter appropriations The inconsistency of using two different kinds of figures, however, is more apparent than real. Appropriations over a long period necessarily approach expenditures very closely in the end, because any unexpended balance of one year's appropriation is carried over to the next year, and the new appropriation is correspondingly reduced. Thus, although appropriations may not equal expenditures in a given year, the total of one will approximate that of the other during a period of ten years. Neither appropriations nor expenditures alone can be used throughout the years studied. No figures for expenditures are available until about 1823; on the other hand, no appropriations were made for the running expense of the Post Office.

[99] Senate Document No. 1, 21 Cong., 1 Sess., p. 46.

[100] Senate Document No. 1, 21 Cong., 2 Sess., p. 52.

whole post office in 1810.[101] The cost of the Western branch of the service cannot be accurately determined for the twenties. A conservative estimate shows an increase from $244,000 in 1821 to $580,000 in 1830.[102]

Inasmuch as the present study deals with current federal operations, a survey of the total cost of the government need not include items that represent obligations incurred in the past. Such items are (1) interest on the public debt, (2) pensions for soldiers of the Revolution and of the War of 1812, (3) payments made to Georgia as a result of the Mississippi cession, and (4) an appropriation of $250,000 for the relief of sufferers in the War of 1812. The following table is an estimate of all the money appropriated between 1820 and 1830 which went for Western needs:*

Year	*Total*	*Western*	*Percent Western*
1821	$9,465,712	$3,167,416	33
1822	8,971,917	2,829,818	31
1823	9,362,791	2,969,735	31
1824	15,304,115	8,316,758	54
1825	11,425,279	4,189,973	36
1826	12,508,980	4,681,880	37
1827	11,761,016	3,731,814	31
1828	14,829,329	4,634,790	31
1829	12,188,960	3,863,808	31
1830	14,338,983	4,556,429	31

[101] House Executive Document No. 505, 23 Cong., 1 Sess., p. 6.

[102] Expense of the post office:

Year	*Total*	*Western*	*Percent Western*
1821	$1,165,481	$244,751	21
1822	1,169,885	245,675	21
1823	1,170,144	245,730	21
1824	1,206,584	265,448	22
1825	1,309,316	301,142	23
1826	1,373,239	329,577	24
1827	1,623,893	422,212	26
1828	1,782,132	496,996	28
1829	1,932,707	579,812	30
1830	1,933,559	580,067	30

—House Executive Document No. 140, 15 Cong., 2 Sess., p. 11; *Idem,* No. 76, 17 Cong., 1 Sess., p. 3; *Idem,* No. 2, 18 Cong., 1 Sess., p. 260; Senate Document No. 1, 18 Cong., 2 Sess., p. 173; *Idem,* No. 2, 19 Cong., 1 Sess., p. 165; *Idem,* No. 1, part IV, 19 Cong., 2 Sess., p. 133; *Idem,* No. 1, 20 Cong., 1 Sess., p. 259; *Idem,* No. 1, 21 Cong., 2 Sess., p. 51; House Executive Document No. 2, 22 Cong., 1 Sess., p. 46.

* See appendix for itemized account for each of the years.

By the time the administration of John Quincy Adams had reached the middle of its course it encountered an attack from its opponents on the issue of federal expenditure. Between January 22 and February 6, 1828, a debate on retrenchment consumed most of the time of both houses.[103] In this debate, three elements of dissatisfaction were perceptible. First appeared the charge that Adams had made corrupt use of the patronage. Secretary Clay, continued the criticism, was guilty of extravagance in managing the State department. Finally, the leaders of the seaboard South expressed their disapproval of the growth of the federal government in general.

"The time has now arrived," said Representative Floyd of Virginia, "when this house is bound to do something decisive in its character. Heretofore the operation of this government has been. in a great degree, beyond our limits, and confined to objects of a constitutional character, but now a new era has opened upon us, and we are about to feel the calamitous consequences which its measures and policies are destined to bring upon the people."[104] A few days later, Representative Rives, also of Virginia, spoke in the same vein: "The tree of Executive patronage is continually throwing out new shoots and branches, which constantly call for the application of the pruning knife."[105] The Adams administration, he continued, had "been in striking contrast with the self-denying republicanism of Mr. Jefferson. Instead of renouncing the exercise of power which the laws and constitution had given them, we have seen them laying claim to powers which are sanctioned by neither; instead of the suppression of unnecessary offices, and the curtailment of Executive patronage, we have seen them rapidly multiplied and increased, under their auspices; instead of recommending the limitation of Executive discretion over the public disbursements, we have seen them asking for large grants of public money, to be expended at their mere will and pleasure."[106]

John Randolph stressed the importance of the sectional aspect of the expansion of the government. In the course of his remarks, he pictured the distress of the Virginia planters. For

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[103] *Abridgement of Debates,* IX, 668–69.
[104] *Ibid.,* IX, 682.
[105] *Ibid.,* IX, 743.
[106] *Ibid.,* IX, 748.

every one of them, he declared, who was making one percent on his investment, twenty others were losing heavily. The country was in "an unexampled state". He could "remember nothing like it", though he recalled the times of Cornwallis's march through the South. "And why is this?" he asked. "Sir, we have been legislated into this thing—would to God, we could be legislated out of it again. . . . But no, sir, our sons must be educated at the public expense, and when the people are in distress we must look from their own or our own improvidence for some road, or some canal, or some woolen manufactory" and "ascribe the disease to anything but the true cause, unwise legislation and prodigality."[107]

In Randolph's estimation, the growth of the West was the source of the woes of his section. The act which had ruined the old South was the cession of the Northwest Territory by Virginia. This had drained off population from the seaboard, extended the frontier, and increased the operations of the federal government. On one occasion during the retrenchment debate he exclaimed: "Sir, it seems I committed a great offense in not voting for the admission of the new States into the Union. . . . Yet sir, if the thing were to do over again, I should act precisely in the same manner, and past experience would teach me I was right. What were the new states? Vast deserts of woods, inhabited by aborigines, to whom if we come to the question of right, they did of right belong; and it was a question whether sound policy would dictate that we ought, by creating these states, encourage sparse settlements, and thereby weaken our frontier. I thought this was bad policy."[108] These remarks were occasioned by his feeling "that the expenses of this government are too high; that they ought to be reduced;"[109]—"that retrenchment is required both by the circumstances of the country, and by the voice of the people."[110]

In reply to the critics of the administration, its defenders asserted that the cost of the government was not abnormally high. It was futile, they said, to expect that cost to remain stationary while the country was growing rapidly—futile to compare the expenditures in Jefferson's day with those of 1827,

[107] *Ibid.*, IX, 677–78.
[108] *Ibid.*, IX, 717.
[109] *Ibid.*, IX, 676.
[110] *Ibid.*, IX, 675.

when the material condition of the country was so greatly altered. Representative Sergeant of Pennsylvania estimated that the expense in 1827 for civil, diplomatic, and miscellaneous purposes amounted to only $2,600,000. "This expenditure . . . ," he explained, "provides for the following objects: The whole of the Legislature of this Union of twenty-four States . . . : the whole of the Executive . . . ; the expenses of the Post Office Department, covering a greater extent of territory, and diffusing a greater amount of accommodation than any other known establishment of that kind: the surveying of the public lands: the Mint establishment of the United States: the Governments of the three territories: the whole Judiciary . . . : the light-house establishment: the whole of the expenses of our foreign intercourse, and some miscellaneous items."[111] "Is it not rather amazing," he asked, "that a Government, extending over twenty-four states and three territories, embracing so large a space, and so great a population, and providing adequately for all, should be carried on at so small an expense?"

The Jacksonian Westerners who rose during the debate complained along with the spokesmen of the old South of the excessive costs of government. But the targets of Western criticism were Clay and his conduct of the foreign office, and Adams's use of the patronage. None of the Westerners complained that too much money was being spent on their section. Yet, when the appropriations of the period are analysed, they show the frontier a principal factor underlying the expanding cost of the federal government. The Western influence is revealed in appropriations for Indian affairs, for the army, for the post office, for the judiciary, for the public lands, for internal improvements, for Congress, for territorial government, and even for the navy. Instead of complaining of the extravagance involved in these expenditures, the Westerners were appealing for larger and larger appropriations,—for schools, roads, canals, removal of Indians, coast defenses, judiciary extension, land surveys, new postal routes, river improvement, and military protection of the frontier. The demand of the Jacksonian Westerners did not strike at the root of expansion

[111] *Ibid.*, IX, 731.
[112] *Ibid.*, IX, 731.

as did the complaints of the seaboard Southerners like John Randolph and Representative Rives.

In the distribution of federal expenditures may be found a source of sectional misunderstanding and conflict. The Easterners and Southerners who realized how much of the cost of the government went to Western uses felt that the West was not a neglected part of the Union. But the Westerners themselves were not satisfied. Despite the money spent in the West, they still felt that they were receiving but a small fraction of the bounty of the government. This condition could exist because the money which was spent *for* the West was spent *in* the East, to the advantage of Eastern merchants and contractors. Consequently, the Western states did not receive the important though incidental benefits of expenditures in the shape of increased sales for local Western merchants, or of an augmented supply of good money necessary for making trade active on the frontier. Therefore, while the Southerners were saying that the West was "amply provided for", the Westerners were saying that federal policies drained their localities of good money, and that the system of public disbursements was designed to keep the West in commercial dependence upon the East.

The growth of the inland frontier after 1815 was one of the principal factors forcing the federal government to expand. Beginning its career as a feeble, restricted body, Congress possessed one source of infinite power—its control over the public lands. With these lands it could do as it pleased; here it could exercise an influence such as it could never exert in the original states. Because of this fact the needs of the West in later days increased the activities of the federal government. Territorial administration, land sales, Indian affairs, the creation of new states—these and other matters gave Congress a sense of the fullness of power. Did not Jefferson abandon strict construction in order to extend the Western territory and to advance in many ways the interests of the frontier? In the years after 1815 the West forced a liberal interpretation of the Constitution on the subject of roads and canals. The line between the old states and the new states became indistinct, and that between the new states and the terriories even more nebulous. By 1830 it seemed apparent to many that a literal

constitution adopted for thirteen small states could not satisfy all the needs of an enlarged nation.

The growth of the country brought new requisitions, multiplied national offices and office-holders, and forced the federal government upon a more extended course than the strict constructionists had ever anticipated. No small part of this growth was the increase of expense to which the frontier contributed in such a material way. The West occasioned more than a third of the federal expenditures at a time when it had only a fourth of the inhabitants of the country. Inasmuch as most Western interests were matters of federal concern, the growth of settlements stimulated that physical expansion of the federal system by which it was transformed from a loose union of a few proud states into a continental government stronger than its single members.

APPENDIX

COST OF THE GOVERNMENT BY YEARS

TABLE I—1811

Total items	*Amount*	*Western items*	*Amount*
Congress	$236,825	Congress	$21,404
Army	2,985,685	Army	1,414,971
Judiciary	105,000	Judiciary	15,750
Indian affairs	163,011	Indian affairs	163,011
Navy	1,920,266	Post office	69,435
Civil, etc.*	745,787	Land office	163,300
Post office	495,969	Territorial Govt.	70,513
Navigation, etc.**	163,072	Navigation, etc.	60,000
Census	150,000	Census	21,000
	$6,995,585		$2,029,384

TABLE II—1820

Total items	*Amount*	*Western items*	*Amount*
Congress	$456,300	Congress	$86,697
Army	4,504,373	Army	2,073,145
Judiciary	87,500	Judiciary	22,750
Indian affairs	462,030	Indian affairs	462,030
Navy	3,992,035	Navy	60,000
Civil, etc.	1,584,801	Land office	317,418
Post office	1,160,926	Territorial Govt.	25,722
Navigation, etc.	382,463	Navigation, etc.	187,300
Census	240,000	Census	55,200
	$12,870,428	Post Office	243,794
			$3,538,554

* Civil, etc.: President, Vice-president, executive officers, public lands, mint, treaty executions, relief of seamen, public buildings, diplomacy, territorial government. revenue service, claims against the government.

** Navigation, etc.: Lighthouses, buoys, river improvement, harbors, roads, canals.

TABLE III—1821

Total items	*Amount*	*Western items*	*Amount*
Congress	$372,816	Congress	$70,835
Army	3,196,974	Army	1,897,983
Judiciary	88,150	Judiciary	22,919
Indian affairs	520,745	Indian affairs	520,745
Navy	2,709,092	Post office	244,751
Civil, etc.	1,281,163	Land office	273,783
Post office	1,165,481	Territorial Govt.	13,900
Navigation, etc.	131,291	Navigation, etc.	5,000
		Acquisition of Florida	117,500
	$9,465,712		$3,167,416

TABLE IV—1822

Total items	*Amount*	*Western items*	*Amount*
Congress	$247,471	Congress	$49,494
Army	2,779,534	Army	1,765,672
Judiciary	112,150	Judiciary	31,402
Indian affairs	482,625	Indian affairs	482,625
Navy	2,716,733	Post office	245,675
Civil, etc.	1,301,101	Land office	225,480
Post office	1,169,885	Territorial Govt.	13,900
Navigation, etc.	162,428	Navigation, etc.	15,570
	$8,971,917		$2,829,818

TABLE V—1823

Total items	*Amount*	*Western items*	*Amount*
Congress	$338,290	Congress	$67,658
Army	2,968,977	Army	1,647,728
Judiciary	154,413	Judiciary	43,236
Indian affairs	389,380	Indian affairs	389,380
Navy	2,993,019	Navy	160,000
Civil, etc.	1,025,207	Land office	313,348
Post office	1,170,144	Territorial Govt.	37,735
Navigation, etc.	333,361	Navigation, etc.	46,920
		Post office	245,730
	$9,362,791	Florida treaty	18,000
			$2,969,735

TABLE VI—1824

Total items	*Amount*	*Western items*	*Amount*
Congress	$791,497	Congress	$205,805
Army	3,039,339	Army	1,762,561
Judiciary	149,500	Judiciary	41,860
Indian affairs	552,805	Indian affairs	552,805
Navy	2,923,663	Post office	265,448
Civil, etc.	1,250,994	Land office	258,801
Post office	1,206,584	Territorial Govt.	31,978
Navigation, etc.	389,633	Navigation, etc.	197,500
Florida Treaty	5,000,000	Florida Treaty	5,000,000
	$15,304,115		$8,316,758

TABLE VII—1825

Total items	*Amount*	*Western items*	*Amount*
Congress	$402,107	Congress	$105,547
Army	3,404,867	Army	1,789,365
Judiciary	290,700	Judiciary	81,396
Indian affairs	777,856	Indian affairs	777,856
Navy	3,654,787	Navy	600,000
Civil, etc.	1,184,822	Land office	277,475
Post office	1,309,316	Territorial Govt.	34,732
Navigation, etc.	400,814	Navigation, etc.	223,460
		Post office	301,142
	$11,425,279		$4,189,973

TABLE VIII—1826

Total items	*Amount*	*Western items*	*Amount*
Congress	$749,265	Congress	$194,808
Army	3,684,385	Army	2,117,321
Judiciary	240,350	Judiciary	67,298
Indian affairs	1,026,196	Indian affairs	1,026,196
Navy	3,587,880	Navy	350,000
Civil, etc.	1,120,311	Land office	237,026
Post office	1,373,239	Territorial Govt.	52,175
Navigation, etc.	727,354	Navigation, etc.	307,479
		Post office	329,577
	$12,508,980		$4,681,880

TABLE IX—1827

Total items	*Amount*	*Western items*	*Amount*
Congress	$433,390	Congress	$112,681
Army	3,481,376	Army	1,934,593
Judiciary	241,611	Judiciary	67,610
Indian affairs	622,068	Indian affairs	622,068
Navy	3,705,746	Post office	422,212
Civil, etc.	1,126,873	Land office	193,031
Post office	1,623,893	Territorial Govt.	37,846
Navigation, etc.	526,059	Navigation, etc.	341,773
	$11,761,016		$3,731,814

TABLE X—1828

Total items	*Amount*	*Western items*	*Amount*
Congress	$578,003	Congress	$151,680
Army	4,438,017	Army	2,275,561
Judiciary	241,100	Judiciary	67,508
Indian affairs	822,282	Indian affairs	822,282
Navy	4,615,750	Navy	201,650
Civil, etc.	1,155,748	Land office	171,515
Post office	1,782,131	Territorial Govt.	56,868
Navigation, etc.	1,196,298	Navigation, etc.	382,230
		Ala. customs house	8,500
	$14,829,329	Post office	496,996
			$4,634,790

TABLE XI—1829

Total items	*Amount*	*Western items*	*Amount*
Congress	$523,748	Congress	$136,174
Army	3,026,905	Army	1,329,680
Judiciary	241,800	Judiciary	67,704
Indian affairs	727,323	Indian affairs	727,323
Navy	3,091,686	Post office	579,812
Civil, etc.	1,267,941	Land office	266,567
Post office	1,932,707	Territorial Govt.	65,185
Navigation, etc.	1,026,850	Navigation, etc.	585,363
Census	350,000	Census	106,000
	$12,188,960		$3,863,808

TABLE XII—1830

Total items	*Amount*	*Western items*	*Amount*
Congress	$670,050	Congress	$174,213
Army	3,924,917	Army	2,013,275
Judiciary	242,673	Judiciary	67,948
Indian affairs	1,072,579	Indian affairs	1,072,579
Navy	4,287,361	Post office	580,067
Civil, etc.	1,178,411	Land office	204,622
Post office	1,933.559	Territorial Govt.	63,919
Navigation, etc.	779,433	Navigation, etc.	379,805
Census	250,000	Census	70,000
	$14,338,983		$4,556,429

WHAT MADE FRENEAU THE FATHER OF AMERICAN PROSE?

HARRY HAYDEN CLARK

Although Philip Freneau is now generally recognized as the father of American poetry, his prose has been completely ignored, principally, no doubt, because it has never been collected from the original newspapers and the inaccessible first edition in which it appeared. It is possible, then, that a service might be rendered American letters by the publication of a selection of Freneau's essays[1] which would illustrate his neglected historical significance as (1) the leading journalist in his day of Jeffersonian and French democracy, as (2) a deistic naturalist, and as (3) the first American master of belletristic prose.

I

Whatever the causes for our earlier aesthetic sterility, it is perhaps more than a coincidence that our first outstanding man of letters was a native of the cosmopolitan middle states, of French descent, a man of secular interests, a democrat and a deist. Poet, navigator, editor, and farmer, Philip Freneau was born in New York in 1752 and grew up on his father's spacious estate at Mount Pleasant, New Jersey. There by the fireside, according to his biographer, "the dreamy youth read very widely, especially in the English poets and Latin classics." *The Rising Glory of America,* a poem read at his graduation from Princeton in 1771, indicates his devotion to poetry and his ardent Americanism. Along with Madison, Brackenridge and Aaron Burr, he had attended nightly mass meetings before bonfires in the college yard to deride submission to the British. In such early work as *The American Village* (1772)

[1] I have made such a collection of Freneau's essays, entitled *The Philosopher of the Forest,* which will be published shortly. In the present essay I have used, with the courteous permission of Harcourt, Brace and Company, a few sentences which appear in my introduction to *Poems of Freneau* (N. Y., 1929) in The American Authors Series.

and *The Pictures of Columbus* (1774) he elaborated his favorite theme that civilization has corrupted the "native innocence" and benevolence of mankind manifest in primitive ages. After trying teaching and satirizing the British, Freneau retired for a couple of years to exotic Santa Cruz, bringing home in 1779 poetry which foreshadowed Poe, Coleridge and Keats. *The British Prison Ship* illustrates the way in which the physical horror of bloodshed and imprisonment served to gear his hitherto rather doctrinaire liberalism to the actual problems at hand. His work contributed to the Philadelphia *Freeman's Journal* from 1781 to 1784 helped to cheer the desponding soldiers from Valley Forge to Yorktown; according to his biographer, his writings were "distributed throughout the army, or posted in some conspicuous place to be memorized." His rollicking patriotic ballads were sold in broadsides at all our ports and were sung by sailors on deck. It is indicative, however, of Freneau's lifelong ability to produce "applied" literature and "pure" literature side by side that most of the eleven numbers of *The Philosopher of the Forest,* were originally contributed to the *Freeman's Journal* during this stormy period.

Attacked for his radicalism, Freneau sought "Nēptune's aid" "to ease the aching heart", bringing his service as master of a coast-line freight vessel to a close in 1790 when he married and returned to journalism. The democratic Jefferson, just returned from Revolutionary Paris where the razing of the Bastille had taught him to respect the power of the masses, had expressed his "wonder and mortification" at finding at home an all but unanimous "preference for the kingly over the republican government." Sensing the coming conflict with the Federalist Hamilton, he offered Freneau the clerkship of foreign languages in the office of the Secretary of State if he would establish a "Whig vehicle of intelligence" to combat Fenno's *Gazette of the United States,* subsidized by the Hamiltonians. Thus Freneau skyrocketed into fame as the editor of the *National Gazette,* the "leading paper in America" from 1791 to 1793; he glorified to issues upon which Jeffersonian democracy was founded, and poured blistering contempt upon such measures as the Federalist monarchial tendencies, ceremony, the assumption of the revolutionary debts, the whiskey taxes, the policy of neutrality toward France in 1793, and the general trend toward coercion which culminated in the Alien and Sedi-

tion Laws of 1798. Honored as the "Poet of the Revolution," Freneau was now attacked by Hamilton as trying to undermine the Federal government while in its employ, as being "hired" to "bite the hand that puts bread in his mouth." Federalists such as Timothy Dwight regarded him as a "mere incendiary, or rather as a despicable tool of bigger incendiaries."

However, popular support was withdrawn from the paper following hostility toward France which developed in 1793, and when his patron Jefferson resigned, and yellow fever stalked the streets of Philadelphia, Freneau retired to his beloved Mount Pleasant to edit his poems and write the *Letters on Various Interesting and Important Subjects* under his favorite locust tree while neglecting his farm. He edited *The Jersey Chronicle* from 1795 to 1796, and the New York *Time-Piece* from 1797 to 1798. Poverty drove him back to sea until 1807. Editions of his poems appeared in 1809 and 1815, the latter edition containing poems on the War of 1812. His last years were melancholy. Fire destroyed his ancestral home in 1815, and, as a result of his improvidence and his weakness for the tavern, foreclosures of mortgages reduced his once ample estate. The gray-haired man of eighty lost his way and his life in a blizzard in 1832, while trying to walk home from Freehold, some two miles distant. The nature whose benevolence he celebrated betrayed him. The most vivid impression of the man is that given by his friend, Dr. John W. Francis:

> "He was somewhat below the ordinary height; in person thin yet muscular, with a firm step, though a little inclined to stoop; his countenance wore traces of care, yet lightened with intelligence as he spoke; he was mild in enunciation, neither rapid nor slow, but clear, distinct, and emphatic. His forehead was rather beyond the medium elevation, his eyes grey, occupying a socket deeper than common; his hair must have been beautiful, it was now thinned and of an iron grey. He was free of all ambitious displays; his habitual expression was pensive. His dress might have passed for that of a farmer." The writer goes on to praise him as a "true patriot" who "might have enjoyed increased facilities had he not enlisted with indiscreet zeal as an advocate of the radical doctrines of the day."

II

What were those "radical doctrines?" What factors helped make Freneau the journalist of Jeffersonian and French democracy? If Federalist political theory, distrusting human nature

and advocating a coercive government to safeguard property, is of Puritan and Whig derivation, democratic political theory in general may be traced (1) to the liberty and equality of the agrarian and cosmopolitan frontier and the masses, (2) to the influence of radical English thinkers such as Locke, Shaftesbury, Priestley, Paine, and Godwin, and (3) to the idealists who heralded the French Revolution. What was Freneau's relation to each of these three influences?

As "the leading editor in America" he became the spokesman of the self-reliant, dissenting, deistic, agrarian, anti-capitalistic, anti-British, optimistic frontier, which Professor Turner has shown to be a primary source of American democracy. He became the spokesman of Hamilton's "people of no particular importance." He turned disdainfully from feudal Europe to "the western frontiers" beyond the Alleganies where a "new and most enchanting region opens, of inexpressible beauty and fertility," and found it "not easy to conceive what will be the greatness and importance of North America in a century or two to come." He ridicules the British attempt "to subjugate a country to which nature never gave them a shadow of right, and whose inaccessibility is, of itself, a standing and insurmountable obstacle to their success." Nature has herself provided for an American destiny both independent and sublime. He describes an oppressed European immigrant, who, seeking "a remote part of the western territory," is disillusioned with the aristocratic East, but who finds as he approaches the Ohio that "things alter for the better." He sympathizes with the resolute farmer who established a home amid "one entire forest," a "wild and savage territory," and whose fashionable daughter-in-law is now ashamed of his manners and relegates him in his old age to "a small out-building." He points out that the "members of the last Congress, who entered the public service with very slender resources, are now among the richest citizens of America" as a result of the Federalists' funding scheme which encouraged the purchase of the frontier patriots' Revolutionary bonds before news of their increased value could reach the back-country. Everywhere he attacks the capitalistic program of the Secretary of the Treasury. Signing himself "One of the Swinish Multitude," who suffered by "public neglect, and the misapplication of the public's money," he asks whether "money might with more profit be laid out in repairing

the roads, than in marine establishments, supporting a standing army, useless embassies, exorbitant salaries." Everywhere, as in *Robert Slender's IDEA of a VISIT to a MODERN GREAT MAN,* the philosopher of the forest resents ceremony, formality, pomp, and display. In a day when society aped the English caste-system, he defended plain living and high thinking, simplicity and equality. He scorns the "fopperies and extravagances" of those who do not live by *"their own proper care and industry."* He glorifies "men of simple, upright, and blameless lives, strangers to all fantastical politeness, vain ceremony, and insincerity." His immediate experience as a poor farmer in debt, as a proud journalist struggling in vain against the forces of caste, capitalism, and Calvinistic Federalism, naturally tended to make him a democrat.

The democracy, however, of Freneau—and of America—was determined not only by practice, by the environment, but also by theory, by European thought, and one must not neglect the motivating force of the "philosopher's" increasing acceptance of English radicalism, of deistic naturalism. Fostered by the rationalism of Descartes and Spinoza, by science, and by the habit of dissent engendered by Protestant individualism, deism had been heralded by such men as Locke, Shaftesbury, Collins, Wollaston, Tindal, Bolingbroke, Pope and Priestley. Partly a reaction against the unnatural Puritan reading of life, this Old World faith found congenial soil on the American frontier which inspired freedom, self-reliance, and optimism instead of the Puritan predestination, passivity, and gloom. Freneau's deism stands in American thought as a bridge from the supernaturalism of Edwards, the dependence upon a "divine and supernatural light," to the naturalism of Emerson, the merging of God and man and nature in that "Unity, that Over-Soul, within which every man's particular being is contained and made one with all other." Silent regarding supernatural revelation, Freneau significantly quotes Paine's faith that the "vast machine"—nature—must have had a "great architect," and "divine author," a creator separate from his creation. Although, unlike the Puritan deity, "he is benevolence itself," he is now powerless to interfere with the natural laws, beneficent but immutable, which he has ordained. Freneau echoes the annotated copy of Pope's *Essay on Man,* which had been in his library since he was nine years old, in exclaiming "all, *all is*

right," and in seeing, in Paine's words, "the Creation" as "the Bible of the Deist":

> "All that we see, about, abroad,
> What is it all, but nature's God?"

The philosopher of the forest is engaged on a book to be called *De anima mundi* which is to prove "the divine and incomprehensible intelligence which pervades and enlivens the immensity of matter."

Of more significance, however, as regards democracy is the fact that Freneau, as well as Jefferson, Franklin and Paine, belonged to the nascent humanitarian movement which, during the latter part of the eighteenth century, inspired a new sympathy for the humble and oppressed, a new faith in reason as the chief agent in furthering human perfectibility, and a new sense of social responsibility. He not only sympathizes with the lot of the farmer and the debtor, but he praises the rural clergyman who is "an utter enemy to slave-keeping. The unhappy African was never beheld in his fields to faint beneath the lashes of an unfeeling tyrant, or to groan out a life of bondage and misery to support his vanity, his wickedness, or his imaginary wants." Thus he finds his religion in his love for humanity and nature, no less in the lowly than in the mighty.

Especially interesting as regards democracy is the conflict which went on in the mind of this transitional figure over the problem of the natural goodness of mankind and the source of evil. Again and again in his early essays we find him agreeing with the conservative moralists of the seventeenth and eighteenth centuries who held with Hobbes that the state of nature is the "state of war," that evil is innate, and that man is actuated by a "perpetual desire of power after power." He laments, for example, that "discord and disorder are interwoven with the nature and constitution of the human race." There is much evidence, however, although Freneau is at times inconsistent, that he came increasingly to accept another sort of philosophy which reached its climax in his day. Locke had taught his pupil Shaftesbury that man is the product of environment and sensation. Shaftesbury had asserted that man must therefore be innately good. Then the radicals, such as Priestley and Godwin, had argued that therefore evil should be charged to the thwarting of naturally good instincts by cor-

rupt institutions and environment. If these could be modified, they asserted, man would be capable of infinite perfection. We have seen that Freneau dealt with this theme in his early primitivistic poems on *The American Village* and *The Pictures of Columbus*. In the tenth number of *The Philosopher of the Forest* he deals with the idyllic paradise of primitive America, peopled by "children of nature"; evil entered with the advent of European civilization. Most interesting, however, is the essay of 1798 which appeared in *The Time-Piece:*

> "Man, in a state of simplicity, uncorrupted by the influence of bad education, bad examples, and bad government, possesses a taste for all that is good and beautiful. He is capable of a degree of moral and intellectual improvement, which advances his nature to a participation with the divine. . . . Pleased with himself and all around him, his heart dilates with benevolence and piety. . . . But where is man to be found thus noble, thus innocent, thus happy? Not in so many parts of the terraqueous globe as he ought to be; but still he is to be found wherever the rights of nature and the virtues of simplicity are not violated or banished by the false refinements, the base artifices of *corrupt-governments*. Unhappily for man, society has been almost universally corrupted, even by the arts intended for its very improvement, and human nature is gradually depraved in its very progress to civilization."

Thus, while Federalists such as Hamilton said that "*every man* ought to be supposed a *knave*," actuated by "*private interest*," who "will not conform to the dictates of reason and justice without restraint," Freneau, like Rousseau and Shelley, held that evil was the result of a government restraining natural benevolence, and he therefore opposed the Federalist doctrine that "there ought to be a principle in government capable of resisting the popular current."

Finally, in addition to crystallizing, by means of journalism, the democracy of the frontier and the dissatisfied masses, in addition to disseminating English deistic naturalism, Freneau did much to popularize French radicalism, which later united with Jeffersonian and frontier equalitarianism to produce Jacksonian democracy. If radical French influence upon our Revolution was relatively slight, America was now getting her own revolutionary doctrines—those of English Whigs such as Locke—on the rebound from France, stripped, significantly, of moral and religious restraint. Mr. S. E. Forman says Freneau was "steeped in the philosophy of Rousseau and Condorcet";

his work abounds in translations and praise of what he calls the "judicious sentiments" of the former. Gratitude for Revolutionary aid from France fostered a receptivity to things French which was most marked from 1791 to 1793 in Philadelphia, where Freneau's office on High Street became a meeting place for French sympathizers. Of French descent, trained in French at Princeton, a broadcaster of Rousseau as clerk of foreign languages for Jefferson, agent for the "French Society of the Patriots of America," the editor of the *National Gazette* and *The Time-Piece* did much to identify the ideals of native democrats with those of the French Revolutionists. When Burke, the "drudge of Britain's dirty work," attacked the French Revolution, Freneau championed Paine's radical reply, *The Rights of Man,* which also served to counteract John Adams' *Davilla.* Mackintosh, Godwin, and Barlow joined the international controversy. In January, 1793, Louis Capet "lost his caput," and England declared war on France, who called for the American aid promised under the treaty of 1778. Citizen Genêt, diplomatic representative of republican France, arrived in Charleston, and began, amid tumultuous acclaim by the democrats, a triumphal progress to Philadelphia. Everywhere Jacobin clubs were organized. Sedate men of affairs donned the *bonnet rouge.* Manners, customs, dress, jewelry, ornaments, perfume—all were *à la française.* Liberty poles were raised in public places. Restaurants introduced French soups, salads, ragouts, fricassees, and olive oil. Only French bread was edible. The stately English minuet gave way to the lively cotillon. The streets of Philadelphia, New York, and even Boston were musical at night with *La Marseillaise* and the carmagnole. And in the midst of it all was Citizen Freneau urging his countrymen to help France overthrow "Kings, priests and nobles," to "speed that golden time when Freedom rules." Who but Freneau could be trusted to prepare the stirring odes for the banquets tendered that correspondent of Rousseau, Citizen Genêt?

But Washington, backed by the Federalists, had issued a Proclamation of Neutrality. The democrats raged. "The publications in Freneau's and Bache's papers," wrote Washington, "are outrages to common decency." Genêt, trusting the masses, appealed to the people over Washington's head. The mass of the people hesitated, and then turned against Genêt.

But the rash Freneau openly addressed The Father of His Country:

> "Sir, let not, I beseech you, the opiate of sycophancy, administered by interested and designing men, lull you into fatal lethargy, at this awful moment. Consider that a first magistrate in every country is no other than a public servant whose conduct is to be governed by the will of the people. . . . Why all this outcry against Mr. Genet, for saying he would appeal to the people? Is the President a consecrated character that an appeal from him must be considered criminal? The minister of France, I hope, will act with firmness and with spirit. The people are his friends, or rather the friends of France, and he will have nothing to apprehend, for as yet the people are sovereign in the United States."

Washington complained to Jefferson of his employee, "that rascal Freneau," but the Secretary of State refused to remove him on the ground that "his paper has saved our constitution, which was galloping fast into monarchy." We have already seen that Freneau was forced to discontinue the paper in the fall of 1793. With the death of Louis XVI, the Reign of Terror, the tyranny of Napoleon, the distrust of French morality, and the friction arising from the X. Y. Z. papers, there came a strong conservative reaction against things French. Freneau omitted most of his poems on the French Revolution from the edition of 1809, after Wordsworth and Coleridge had recanted their similar enthusiasm. Nevertheless, Jefferson, the friend of France, was raised to the presidency in 1801. "Freneau's paper did much to give a French coloring to our political philosophy," says Mr. S. E. Forman, summarizing his careful study. "The editor of the National Gazette was the schoolmaster who drilled Jeffersonian or French democracy into the minds—willing or unwilling—of the American people." Thus Freneau vigorously allied himself with all three of the democratic influences in America—the frontier and the masses; English deistic naturalism; and French radicalism.

III

The background of Freneau's age not only helps to explain his democracy; it also helps to explain why he was our first master of belletristic prose and why native "pure" prose was so late a development. A frontier society, hewing homes out of a wilderness, is necessarily practical, motor-minded, and without leisure either for reading or writing "mere literature." New

England Puritanism, with its other-worldly indifference toward physical beauty and its militant zeal to refute and to teach, did not tend to foster a literature of pure beauty. Something may perhaps be charged to a relatively plebian population, withdrawn from world-culture and from the possibilities of leisurely discussion and mutual inspiration such as existed at the Elizabethan Mermaid or the Queen Anne coffee-houses. Of course the eighteenth century in general, even in England, was an age of "applied" prose, primarily utilitarian, rational, and hostile toward the emotional release which underlies artistic creation. Even when urban life dispelled the isolation and exigencies of the frontier, and even when sunny and tolerant deism had undermined Puritanism, political controversy, culminating in the Revolution, encouraged the literature of debate rather than "literature as an expression of the aesthetic mood, literature apart from mere instruction." "The foremost representative of this new literary tendency," Professor Tyler concludes, "was Philip Freneau, a true man of genius." He characterizes his prose style as "delightful, easy, sinewy, touched with a delicate humor, crisp and keen edged." Notwithstanding Freneau's political interests, there is much evidence that at heart he was primarily an artist.

What forces helped mould this prose? A detailed search for Freneau's sources might yield some interesting results. For the present one may observe that the influence of "godlike Addison," and Steele, whose *Spectator* was among Freneau's few annotated books, is suggested by the biographical introduction and conclusion to the first number of *The Philosopher,* by the device of having the essays anonymously printed by one in rural retirement, by the vein of sentiment and satire, and by the fact that the device in *The Journal of Timberoo Tabo-eede* of reproducing the naive comments of a savage upon the manners and customs of a civilized community appears in numbers 50 and 171 of the *Spectator.* This latter device appears also, of course, in Goldsmith's *The Citizen of the World,* which offers many suggestive parallels. The satirical and symbolical description of the Island of Snatchaway (England) as well as the frequent tendency toward fantastic and strange experiences reminds one of Swift's *Gulliver's Travels.* The author of *Rasselas,* whom Freneau read, may have suggested the idea of having the philosopher of the forest discuss such themes as

natural goodness, primitivism, and happiness as the reward for virtue. Freneau's study of Gray, Goldsmith, and Burns must have acquainted him with the themes of rustic simplicity, pensive retrospect, the evils of luxury, and gentle melancholy, all of which were congenial to the lettered farmer who retired to Mount Pleasant. The "savage notions of valour and romantic heroism" of Valhalla and the *Scandinavian War Song* in the last number of *The Philosopher* he may have found in Hugh Blair's *Critical Dissertation on the Poems of Ossian* (1763) or in W. B. Stevens' *Poems Consisting of Indian Odes* (1775). *The Inexorable Captain,* A Short Story, heralds this important genre in our native letters and stands as a bridge between Irving and the "moral tale" dear to Hannah More.

Freneau's main trend, however, was by no means either imitative or reactionary. His deistic naturalism had fruitful aesthetic results which have been generally ignored. For naturalism, the faith that "all that we see" is but "nature's God," inspired him to find, like Emerson, the miraculous in the common, and furnished philosophic sanction for treating the actual life of the American field and forest. The setting of *The Philosopher* is "a forest of considerable extent on the western side of the Delaware, not many miles from the beautiful and populous city of Philadelphia." In an age of generality and abstraction he had the artist's instinct for the concrete and the particular. This fresh attention to "the mighty world of ear and eye" enabled him to transmute his ideas into images, to clothe his thought with beauty. Few readers know that Whitman's plea for a distinctively American literature as the product of democracy was first voiced by Freneau:

> "Real poetry, however, will one day have its resurrection; but its professors will no longer be court sycophants, or miserable dependents upon what are called the great. The republican virtues will be their greatest theme, and the promotion of good will, peace, and friendship among men their main object, instead of singing the bloody battles, and rehearsing the military praises of crowned murderers."

Freneau's deistic naturalism has still another result; it causes him to be haunted with the dread of transience, mutability and oblivion, and so raises his best work above ephemeral contemporary affairs to the plane of universality, touching it with a gentle wistfulness and beauty. Naturalism masquerading as a religion lured him to focus his interests upon nature, upon sen-

suous life, and he discovered—as all discover—that sensuous life is forever changing, forever fleeting:

> "The mountains waste, the shores decay,
> Once purling streams are dead and dry—
> 'Twas Nature's work—'tis Nature's play,
> And Nature says that all must die."

Mankind's "doom is to be once more resolved into their original, distinct composing elements, and when that is effected, it is of small importance in what manner it may have been brought about." He amuses himself

> "with reading the various inscriptions on the tombstones; in reflecting upon the momentary continuance of the race of man in the present state of being; and in considering the mortifying change that is here effected from what was once estimated vigorous, brave, gay, sensible, or beautiful."

Elsewhere he represents life as a plain which is "the passage of all mankind into the ocean of forgetfulness, and through this temple, which is dedicated to *oblivion,* every individual without exception is once doomed to pass."

Thus, in general terms, *The Philosopher of the Forest* may be seen as a result of the interplay of the American environment and liberal European thought as they met in that ardent, inexplicable personality which was Freneau. We have seen how the natural goodness doctrine of English deistic naturalism and French radicalism, in connection with the American frontier spirit, helped to motivate his democracy. And we have seen how Old World deism helped to make the philosopher of the forest our first man of letters: for the deistic faith that nature is a divine revelation, accepted by a man surrounded by the natural beauty of the New World, tended to sanctify the American scene to the uses of literature; it gave him means wherewith to wrap his thought with natural beauty; and it tended to impress him with his master-theme—the transient loveliness of a sensuous world and the haunting certainty of inexorable oblivion.

KARNOEFFELSPIEL, A GERMAN CARD GAME OF THE SIXTEENTH CENTURY

ERNST VOSS

If I were writing this in German I would say that the meaning and origin of the word *karnöffel* and its variations *karniffel, karnüffel, karnuffel* and the card game, called *karnöffelspiel,* is indeed eine "kniffelige Geschichte," a knotty, a hard proposition.

The word *karnöffel* occurs as far back as the fifteenth century. The lexicographers of that time do not mention it, but it has been handed down to us in a poem that J. C. von Fichard republished in the *Frankfurtisches Archiv für ältere deutsche Litteratur und Geschichte, dritter Theil,* on pages 293–297, entitled: "Eyn suberlich höfflich spruch von dem spiel karnoffelin." In this "spruch" *karnöffel* refers to the card, called the evil one. This "spruch" on the *karnöffelin* antedates the satire: *Ein frage des gantzen heiligen Ordens der Kartenspieler vom Karnöffel an das Concilium zu Mantua,* 1537, which is reprinted from the copy in the Ducal library at Wolfenbüttel in the Wood Number of *Modern Philology,* 1929. This is a very clever satire of the first half of the sixteenth century on the existing conditions of the church of those days. The next piece of literature dealing with the *Karnöffelspiel* is a Pasquillus of the year 1546, bearing the title: *Newe Zeytung vom Teuffel.* In this pasquil an exact account is given of the chief cards and their value in the *Karnöffelspiel* and *karnöffel* is explained as referring to the cardinals of the church. The last literary document that deals with the *Karnöffelspiel* is Cyriacus Spangenberg's "Wider die böse Sieben ins Teuffels Karnöffelspiel," published in 1562, in which Spangenberg also reprints the before mentioned "Question addressed by the members of the holy Order of the Karnöffelplayers to the Church Council of Mantua", printed in 1537, for he is afraid that in the rush of other unimportant business it might have been overlooked by the authorities of the Church. I intend to have all these documentary evidences reprinted in the near future in order to put together all the material on this subject that might throw light

on this strange game of cards with which every one must have been familiar in the sixteenth century when the great struggle was going on within the Church.

As far as I have been able to ascertain the *Karnöffelspiel* was discussed at length in an article that appeared in the *Teutscher Merkur,* Jahrgang 1777, pages 32ff: "Zur Geschichte des Karnöffelspiels" and again, *Teutscher Merkur,* year 1783, pages 62ff in a "Beytrag zur Geschichte der Kartenspiele." In the *Historisches Jahrbuch,* edited by Friedrich von Raumer, Neunter Jahrgang, pages 321–524, we have finally a long article by Johannes Voigt: "Uber Pasquille, Spottlieder und Schmähschriften aus der ersten Hälfte des XVI Jahrhunderts," in which the *Karnöffelspiel* is fully discussed. C. F. Flögel, *Geschichte der komischen Literatur,* Bd. III, pages 320–324 also speaks of the *Karnöffelspiel* referred to by Cyriacus Spangenberg in his satire, *Against the Evil Seven.*

In *Teutscher Merkur* of the year 1783, the author of the article, "Contribution to the History of Cardgames," calls attention to the fact that the *Karnöffelspiel* must have been known before the Reformation of the Church set in, since Geiler von Kaysersberg, the famous Strassburg priest, mentions it in a sermon that he delivered on Thursday after Judica in the year 1496. This sermon is to be found in the *Book about the Human Tree. A sermon preached by the very learned Doctor Johannes Keysersberg., from which one may learn how to be ready with a cheerful heart and praise of God to receive Death, the All-Destroyer, in all serenity. Good and useful for everybody.* Strassburg 1521.

In this sermon is the following paragraph: In former times it was a simple thing to play at cards. The King trumped the Jack and always the higher card trumped the lower one, but nowadays they play a card game, they call it Karnöffelgame (Karniffelius), in which everything is topsy-turvy, the Threes trump a King, the Fours trump a Jack, the Two and the Six trump a King and when after a new deal they turn up a card for trump, it may come about that in one deal one card is Emperor, in another deal another card, just as luck will have it. In the Latin original the main part reads as follows: But now they have invented a game, which they call the Kaiser game or Karniffelius, in which all this has been perverted (turned around) in such a way that a Three can trump a Jack,

a Two a King and the vicissitudes of the Emperors are still worse, for it depends entirely upon the drawing of the trump card, whether they shall be emperors or not.

This sermon is contained in *Das Buch de Arbore Humana. Von dem menschlichen Baum. Gepredigt von dem hochgelehrten D. Johannes Keysersberg, darinn geschicklich und in Gottes Lob zu lernen ist, des Holzmeiers, des Todes, fröhlich zu warten. Einem jeden Menschen nütz und gut. Strassburg 1521, fol.* In this sermon we find the following paragraph: Vor Zeiten war es gar ein schlechtes Ding zu spielen auf der Karten; der König stach den Obern, und ie das mehrere das Untere, zwei stachen nie einen König. Aber itzt hat man ein Spiel, heisset der Karnöffelspiel (Karniffelius), da seyn alle Dinge verkehrt, die drey stechen ein Ober, die Vier den Untern, zwey und sechs stechen einen König, und so schlägt man um, itzt so ist einerley Kaiser, darnach so wird ein anderley Kaiser, wie das Glück gibt.

In the Latin original the main part of this paragraph reads as follows: Sed nunc ludus inventus qui appellatur (Keiserspil) ludus Caesaris, vel (Karniffelius), in quo haec omnia pervertuntur; ita ut tria vincant superiorem, duo regem, fitque mira vicissitudo Caesarum, ut in hoc ludo iam de hoc coetu, iam de alio fiat Caesar ad fortunam. From this it is clear, says the author of this article, that the *Karnöffelspiel* and the *Kaiserspiel* must have been one and the same and that, although we do no longer know the exact rules of the game, the Emperor (Caesar) played no doubt a very prominent part in it. In any case it was already a current game and not an entirely new one, because otherwise the preacher could not have made himself clear to his large Strassburg congregation. That he does not mention the other cards, as the Pope, the Banner, the Devil, the Seven, from that we have no right to draw the conclusion that these cards were missing in the game in 1496. For what was uppermost in Geiler's mind when he referred to this game was the idea that everything had been turned upside down in this game of cards, for he wanted to use it as an illustration of the tremendous upheavals going on in Church and State in his times, the Reformation of the Church, the Peasant War, etc.

"Hieraus erhellt," says the author of this article, "dass Karnöffeln und Kaiserspiel Eins war, und dasz, ob man wohl die Regeln des Spiels nicht mehr weisz, doch wohl der Kaiser

eine Hauptrolle darinne haben mochte. In allen Fällen war es doch schon ein currentes, und daher nicht ganz neues Spiel; weil ausserdem der Prediger seiner zahlreichen Strassburger Gemeinde nicht verständlich gewesen sein würde. Dass er des Pabsts, Panniers, Teufels, der Sieben nicht gedenkt, daraus folgte zwar eben nicht, dass 1496 diese Blätter im Spiel fehlten. Denn Geiler hatte die Hauptidee des Verkehrten bei dem Spiele vor Augen, um es mit dem Verkehrten seiner damaligen Zeit zu vergleichen."

Hans Sachs also was familiar with this game; he mentions it in one of his plays, where he makes one of the troopers recite a number of German card games. He says:

> Kann auch ein Spiel, heisst ein und dreissig.
> Das hab ich oft getrieben fleissig,
> Dergleichen ein Spiel heisst das Karnöffeln,
> Thät mich auch oft äffen und löffeln.

From the author of the article in *Teutscher Merkur,* 1783, we learn further that even in his days, at the end of the eighteenth century, the farmers of Thuringia were still playing this game of cards, the *Karnöffelspiel,* in a modified form.

He describes the play as he saw it played by the peasants as follows:

This game is played with ordinary German cards and not, as Adelung, the author of the famous *German Dictionary,* the forerunner of Grimms *Deutsches Wörterbuch,* will have it with cards especially designed for this game. The four suits in a deck of German cards are called: Eichel (acorn), Grün (clover, green), Rot (hearts), Schellen (bells), corresponding to our Clubs, Spades, Hearts, Diamonds. The green Eight (eight of spades) which is called the Dare Devil, der Tolle or the Old Beast (das alte Thier) is the highest card in the deck. The Nine of Hearts (die rote Neun) is called the Red Beast (das rote Thier) and ranks next. Then comes the Nine of Diamonds (the Schellen Neun) or the Yellow Beast. Whatever suit may be trumps these three cards come first. If their own suit should be trumps, the other cards in the trump suit rank as follows: First the Obermann (our queen) and he is called the Oberkarniffel or Landsknecht, i. e., the trooper, next the Untermann, subnamed the Unterkarniffel or also Büttel, the beadle (in our card games the Jack). Then comes the Six, subnamed

the Papst (the Pope) and after that the cards rank as follows, the Eight (except of course the Eight of Spades) and the Nine (with the exception of the Nine of Hearts and the Nine of Diamonds). These last two cards are called Freykarten (free cards), probably because they cannot be trumped, unless their suit should be trumps.

The Dauss (our Ace) according to old style the Kaiser, the King, the Ten (also called the Pannier, the banner) are the lowest cards in the deck and worthless.

With regard to the Seven it must be noticed that it cannot be trumped at all and that it can only be played after the player who leads has made at least one trick. On that account it is named the Böse Sieben, or according to the older phraseology, Der Teufel. In the other suits that are not trumps (always two suits are trumps in this strange game) the rank of the cards is the following: Obermann, Untermann, Sechs, Acht, Neun, Dauss, König, Zehen. The Ober- and Untermann are nicknamed the Fauler Schlingel (lazy rascal), formerly Fauler Fritz (lazy Freddy), because they cannot trump and are inactive until all the other trumps have been used up.

Four or six persons play this game in two parties. Each player gets five cards. The dealer, when through dealing, puts the next two cards face up on the table and these indicate the two trump suits. He who holds trump Ten in his hand may exchange it for one of the two trump cards put on the table if they are of higher value. If both of the cards drawn for trumps are of the same color, another card must be drawn from the deck on the table until two different suits are revealed. Both trump suits thus established have the same value. While the game is on, in following suit, the higher card must always be played, the cards that are lower than the one played out are kept back. Each side of the players chooses a director who may look into the hands of those that play with him on his side, and if he sees fit, he may give up the game if nothing can be gained by the cards that his party holds. The number of tricks made decides the game and the stake goes to the winner. Nowadays the Karnöffelspiel seems to be unknown in Germany. Other games, like Sixty-Six, Schafskopf, Skat and others have taken its place, but anyone familiar with German card games will recognize traces of the Karnöffelspiel in most of the modern card games. In the German game, called Skat (from

Italian, scarto) the Jacks are always the highest cards; they have taken the place of the Unterkarnöffel.

So much about the history of the Karnöffelspiel. In another paper I shall take up the etymology of Karnöffel and review the attempts that have been made to explain the origin and meaning of this puzzling word.

AN ORDINANCE OF THE CITY OF FRANKFORT OF THE YEAR 1597 REGULATING DRESSES, MARRIAGES, BAPTISMS, ETC.

ERNST VOSS

The student of history must see a striking resemblance between the Sixteenth Century and our own times.

We are accustomed to refer to the former period as the time of the Reformation, usually meaning the reformation of religious thought. It was however a period of *general* movement for reform, a time of restlessness expressing itself in various attempts towards change in laws, customs and government.

It was during this time that the unparalleled uprising known as the Peasants' War occurred; and the records of the day are full of the demands made by the less favored for recognition both in heaven and on earth.

Luxury and extravagance were cried out against strongly enough to create and enforce stringent laws for the regulation of expense in those great ceremonials of a man's life, birth, marriage and death.

In these days when the high cost of living and the expense of a respectable burial make it equally hard to live or to die and forces man anew between the fateful rocks of Scylla and Charybdis, it may be interesting to learn that men of other ages have struggled with our own problems in much the same way.

The ordinance of the City Council of Frankfort reprinted here was issued in 1598 and speaks for itself of the abuses which had grown intolerable enough to demand such an ordinance.

The title reads as follows:

Erneuerte Policey Ordnung, vnnd Satzung eines Erbarn Raths dieser Statt Franckfort, wie es hinführo mit Kleydungen, Hochzeiten, Kind Tauffen, Kindbetthaltung und dergleichen gehalten werden soll.

You see that it does not only refer to baptismals and marriage festivals but also to dress, certainly a most important point as every married man can easily understand. The word "erneuert" means that this is not a new ordinance but that something similar had been passed and published before by the

City Council, as far back as 1576. From the introduction to this ordinance we learn that laws against overdressing as well as overeating and overdrinking had been enacted by several German Diets and published in the so-called *Reichsabschiede,* for in those days the people were informed, contrary to our custom, about what the diet had accomplished and not what it merely intended or promised to do while in session. I give a few excerpts only in English to indicate the spirit of this Frankfort ordinance.

Men's Dress

With reference to dress no man of the citizen class, Bürger, is permitted to wear a coat or a mantilla made of Sammet (velvet), Damask, Ormasin, Atlasz (satin), or any other kind of silk, except those who are freed from this restriction through their position in life, i. e., men of nobility, free knights and doctors, which means of course not only doctors of medicine, but doctors of law, philosophy and theology as well. The punishment for disobeying this law is 4 Gulden.

Other distinguished citizens, wealthy merchants and tradesmen, also members of the common council, will be allowed to use two yards of Sammet (velvet) to border their coats and mantillas. No man shall be allowed to wear knitted stockings that cost more than 4 or 5 Gulden (2 marks). It is also forbidden to embroider silk garments with golden or silver borders, nothing but silk borders to be used. The tailors and workers in silk are also warned to look out for whom they are working, as they are liable to punishment as well. Silk (sammet or velvet) caps or hats can only be worn by men of the nobility, those citizens of the first rank. To wear golden chains around the neck is permitted only to those who have enjoyed this privilege for ages. In no case however, shall the golden chains represent more than 150 crowns. The collars worn by the noblemen must not cost more than 6 Gulden. Common citizens are not allowed to spend more than 4 Gulden for their collars and these must not be higher than ⅛ of a yard.

Women's Dress

No woman is allowed to wear a Rock (skirt) or cloak of golden or silver cloth, nor entirely of velvet (sammet). No pearls, golden or silver embroidery are allowed on the garments.

Silk garments are allowed to the women of rank only. These may also wear golden headgear and chains, but they must not cost more than 100 crowns, those of an unmarried woman not more than 40 crowns. Golden rings are allowed, but not more than six at a time. Also jewelry around the neck and a pearl chain, and a couple of golden arm bracelets, representing however not more than 30 or at the highest 40 crowns.

Women of the second and third class are forbidden to wear garments made of silk or velvet. Their belts (gürtel) must not cost more than 40 Gulden. They are allowed only four golden rings, and necklaces costing not more than 10 Gulden. Belts made entirely of silver, golden chains, necklaces and hair ornaments they are forbidden to wear.

Women of the artisan class, the fourth class

Special restriction with reference to dress.

Also special restrictions with reference to servants' dress. Servants belong to the fifth class. Special regulations for the collars worn by women of this class, the size is prescribed as well as material and price.

Women of the first class must not spend more than 6 Gulden for a collar, women of the second class and third class not more than 4 Gulden, of the fourth and fifth class not more than two Gulden.

Aufschläge, cuffs on coats and mantillas, width and material prescribed.

Veils, size and material regulated.

Headgear made of fur is also regulated.

Zabel and martin only for women of the first rank.

Fur linings only for ladies of the nobility, doctors' wives, and those of the patricians.

Marriage Festivals

1576 already regulated.

Same ordinance regulating weddings, geschenkte und ungeschenkte Hochzeiten, festivities without and with presents.

Ungeschenkte oder freie Hochzeiten in vogue with the nobility and citizens of the first class, patricians.

Not more than ten tables to be invited. Penalty: 3 Gulden for each extra table.

Geschenkte Hochzeiten.

Invite only nearest relatives of bride and bridegroom, for every other person penalty 3 Gulden.

Brides. There may be invited eight couples, sixteen persons, not more. The invited guests must be at least 18 years old.

Meals—Wedding Feasts

Two the first day.

One the following, an evening meal. Strangers may be entertained the evening before the wedding and also at dinner the day after the wedding. All extras are abolished, like drives into neighboring villages; procession in the streets headed by a band and drinking bouts after the marriage. Not more than three musicians allowed except to citizens of the first class.

Sending meals (Brautsuppen) to persons outside also prohibited, except to near relatives who are unable to be present at the festivities. The cook in charge of the meals to be paid not more than 5 Gulden, the woman cook the same, the chambermaid two Gulden.

At a common wedding only half this price.

Waiters and doorkeepers' wages are also regulated.

At the Schenkhochzeiten relatives may give as much as they please to the bride and bridegroom. Guests invited, not relatives, shall give no more than a Gold Gulden, bachelors give half a crown, or twelve shillings, unmarried ladies 8 shillings.

Dinner shall begin at eleven. Supper begins at seven, and must not last more than 3 hours. Invited guests found after 11:15 in the evening at the inn or the dancing hall, where the marriage festivals were celebrated, will be fined half a Gulden.

Festive Meals Regulated

Not more than 3 chief courses, including the cheese course, and two side courses of meat or fish. With the cheese, fruit or pastry may be served.

Noblemen and patricians are allowed for every chief course three or four side courses.

Nightcaps (Schlafftrunk) after the meals are no longer allowed except when strangers of rank are invited to festivities.

Bridal shoes heretofore made at great cost of velvet, plush, embroidered with gold, silver, silk and pearls must from now

on cost no more than one Gulden. The man that makes them at a higher price is punished as well as the one that buys them.

Baptismals

Invitations limited and strictly regulated. Not more than 12 ladies, except in the case of noblemen and patricians. They are however asked to be moderate and give a good example. People invited to a baptismal as god fathers or mothers may give presents at their discretion, if they are relatives. Outsiders must not spend more than two Gulden on the child. Cakes for the young mother are abolished. Elaborate meals after the ceremony are forbidden. A man may invite his friends before the baptismal to a good time at the guild hall, but the festivity must stop there and not be continued at the home of the father of the child newly born. Godfathers are forbidden also to give to the child at the age of five, as has been customary so far, elaborate and costly suits of clothing. However, it is permissible to present to the newly born four weeks after the baptismal a shirt or nightgown that must cost no more than two or at the highest three Gulden.

The buyer as well as the maker is fined.

ERNEWERTE POLICEY ORDNUNG, VNND SATZUNG EINES ERBARN RATHS DIESER STATT FRANCKFORT, WIE ES HINFUEHRO MIT KLEYDUNGEN, HOCHZEITEN, KIND TAUFFEN, KINDBETTHALTUNG VND DERGLEICHEN, GEHALTEN WERDEN SOLL

Stadtwappen

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Kleyder Ordnung

Obwol an sich selbsten Ehrlich, zimlich, vnd billich, dasz ein jeder, was Wuerden, Standts, oder Herkommens der seye, nach seinem Standt, Ehren, vnd Vermoegen sich trage, vnnd also bekleyden lasse, damit ein jeder in seinem Standt vnterschiedlich erkannt werden moege: So vernimbt man jedoch,

vnd bezeuget es die taegliche Erfahrung, dasz der vbermaessige Pracht, Stoltz, vnd Hoffarth in der Kleydung, so wol auch der Vberflusz in Essen und Trincken, vnnd andern Sachen mehr, dermassen vberhand genommen, vnd so hoch gestiegen, dasz dardurch nicht allein Priuat Personen, sondern auch gantze Landtschafften in Abgang jhrer zeitlichen Nahrung vnnd derselben Ringerung gerahten, Zu geschweigen, wie gar kein vnterscheid der Personen, eines oder desz andern Standts, solcher Vbermasz wegen erkannt vnnd abgenommen werden moege. Dannenhero ein jede Christliche Oberkeit so wol ausz den Reichs Abschieden, als auch fuernemblich ausz Gottes Wort erinnerlichen angemahnet wirdt, solchem einreissendem Vbel, der Gebuer, abzuwehren vnd zusteuwren. (Aij)

Ob auch wol ein Erbarer Raht dieser desz H. Reichs Statt Franckfort disz fals, so viel an jhme, als einer Christlichen Oberkeit, nichts erwinden, sondern in Anno 1576. derwegen, vnd wie es bey seinen Vnterthanen vnd Buergern, in Gastmahlen, vnnd Hochzeiten, deszgleichen bey Kind Tauffen, vnd mit der Kleydung allerseits gehalten werden solle, eine ziemliche vnd leidenliche Policey Ordnung verfasset, vnd dieselbe, zu maennigliches nachrichtung, *publicirn*, auch mit angehenckten Straffen versehen lassen, Auch anders nicht, sondern gentzlichen darfuer geachtet, dann es wuerde derselben Ordnung von jederman gelebt, vnd der Gebuer schueldige Volge beschehen seyn. So hat sich doch, leyder, in Gegenfall der Widersinn erwiesen, vnd dasz nicht allein vorgedachtes eines Erbarn Rahts vaetterliche vnd wolmeinende Vorsorg vnd auffgerichte Ordnung veraechtlichen in Wind geschlagen, sondern auch derselben zuentgegen, der hochschaedliche Miszbrauch der Kleyder, so wol auch der verdambliche Vberflusz in Essen vnd Trincken, je mehr vnd mehr gestiegen seye, augenscheinlich befunden. Derohalben dann mehr wolgedachter ein Erbarer Raht Oberkeitlichen Ampts halben nicht vnterlassen koennen, deszwegen gebuerliches Einsehen zu haben, vnd die hiebevor auffgerichte Ordnung etlicher massen zuschaerpffen, vnd zuerneuwern. Wil demnach vnd ordnet, dasz alle vnnd jede, jhre, so wol Teutscher als Welscher oder anderer Nation, zu: vnd angehoerige Buerger vnd Vnterthanen, Manns vnd Weibs Personen, sich nachvolgender Ordnung, in allen jhren Puncten vnnd Articuln gehorsamb vnd gemesz verhalten, vnd, bey denen darinn bestimpten Straffen, derselben nicht zuwider

handlen. Dasz auch, ingleichem, die jederzeit zum Send* verordnete, vermoeg hiemit jhnen ernstlich aufferlegten Befelchs, steiff vnnd fest darueber halten, vnnd gute Achtung darauff geben sollen, damit gemelter Ordnung, obbegriffener massen, wuercklichen gelebt, vnd, in verbrechung deren, niemand nachgesehen werde: Wie dann gemelte jederzeit zum Send verordnete, die Vberfahrer derselben, wo ferrn sie sich der gesetzen Straffen nicht vnterwerffen woelten, obernanntem einem Erbarn Raht anbringen, vnd dessen fernern Bescheidts darueber gewertig seyn sollen.

Vnd erstlich, so viel die Manns Personen belanget, ist eins Erbarn Raths Will vnd Meynung, dasz hinfuero kein Buerger, Vnterthan, oder Beysesz, einigen Rock oder Mantel von Sammat, Damast, Ormasin, Atlasz, oder anderm Seydengewandt nicht tragen soll. (Auszgenommen die jenigen, so jres stands halben dessen gefreyet seynd, Als die vom Adel, Ritter vnd *Doctores.*) Doch moegen die Erbarn von den Geschlechten, sammete, dammaste, ormasin, atlasz, vnnd dergleichen Wammes, Leibroecklein, vnnd Kleyder antragen. Es moegen auch jetztgedachte Manns Personen jhr (Aiij) Roeck vnd Maentel, mit drey elen Sammat verbraemen oder vnterfuettern lassen. Bey straff 4. guelden.

Was sonst andere namhaffte Buerger, Auch statliche Haendler vnd Kauffleuth, dergleichen die Rathspersonen, vnd eines Erbarn Raths vertrauwte vnnd fuernemme der Cantzlei verwandte Diener, belanget, die moegen sich zwoer eln Sammat, damit jre Roeck vnd Maentel zuverbraemen, wol gebrauchen, Auch sonst allen andern seydenen Zeug (ausserhalb) Sammat, seyden Rupff, doppeln seydenen Grobgruen, Niderlaendischen Gaffa, Floret vnd seyden Trieb) allein zu Wammes, aber nit zu Hosen antragen. Bey obgemelter straff der vier guelden. Andere fuernemme Kraemer aber, wie gleichsfalls die *Notarij, Procuratores,* vnnd so ohngefaehrlich dessen Stands seynd, sollen mehr nicht, dann eine elen Sammats, zu verbraemung jhrer Roeck oder Kleydung, zugebrauchen, macht haben.

Sonsten sol nechstgemelten, vnd in gemein, allen andern Mannspersonen vnd jungen Gesellen, aller Sammat vnd Seydengewandt, zu Wammes, oder Hosengesesz, verbotten: Gleich wol

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* Gerichtsversammlung, aus griech. lat. synodus. Ags. seonod, ahd. sënot, mhd. sent.

aber Zendel dort, seyden Schamlott, gemeiner Taffet, vnnd Grobgruen, zu halber oder gantzer Kleydung, anzutragen, erlaubt seyn, Bey straff zehen Guelden.

Es sol auch hinfuero kein Manns Person oder junger Gesell gestrickte Struempff, so vber vier, oder zum hoechsten, fuenff Guelden werth seyn, antragen, bey straff zween Guelden.

Es sol auch hinfuero, sammate, damaste, atlase, vnd dergleichen seydene Kleydung, weder mit gueldenen, silberen, oder andern statlichen, sondern allein mit seydenen Schnueren, zu verbraemen vnd zubelegen zugelassen seyn. Sonst moegen die Erbarn von den Geschlechten, Leder, oder andern schlechten Zeug, so nicht seyden, mit einem silbern schnuerlein, bescheidenlich: Die andere Manns Personen aber alle, mit einem seydenen schnuerlein belegen. Bey straff sechs Guelden.

Alles sticken vnd steppen aber, es sey durch Schneider, Seydensticker, Naeherin, oder andere Personen, sol ferner, dann hievor gemeldet, auch solche Kleydung anzutragen, gaentzlich verbotten seyn. Bey straff zehen guelden.

Die sammete Paret, Hauben vnd Huet, moegen allein die Erbare von den Geschlechten, vnd so gefreyetes Stands seynd, wie obgemelt, Auch Perline Hutschnuer, ohngefaehrlich 20. guelden werth, aufftragen. Andern aber, dieselbe durch ausz verbotten seyn. Bey straff dreyer guelden.

Item, gueldene Ketten, wie auch seydene, vnd andere dergleichen Halszschnuer zutragen, seynd allein denen Manns Personen, die es von alters hero vehig gewest, zugelassen. Doch sol deren keiner einige gueldene Ketten vber 150. Kronen werth antragen. Die Halszschnuer aber allen andern hiemit gaentzlich verbotten seyn. Bey straff zehen Guelden.

Manns Kroesz vnd Kragen anlangend (damit biszhero vbermaessiger Pracht getrieben worden) ist den Erbarn von den Geschlechten zugelassen, Kraegen vnd Kroesz so mit Leinwath, Macherlohn vnd allem, sechs guelden werth, vnd nicht vber drey sechzehendtheil einer Elen hoch seynd, zutragen.

Der andern Namhafften, wie auch der gemeinen Buerger Kroesz vnd Kraegen, sollen, mit Macherlohn, Leinwath vnd allem, keines vber vier, vnd zweyer guelden werth, *respectiue,* Auch nicht vber ein halb viertheil einer Elen hoch seyn. Aber die hohe, lange, doppele vnd vngestalte Kroesz, an Kraegen vnd Ermeln, wie auch die Spitzen an denselben zutragen, sol maenniglichen verbotten seyn. Alles bey straff dreyer Guelden.

Was dann die Hantwercks Gesellen anlanget, moegen sie jhre Kleyder, wie sie dieselbe mit sich hieher bringen, zween Monat lang nach *publication* dieser Ordnung also tragen: Wo sie aber darueber allhie bleiben woellen, so sollen sie sich dieser Ordnung gemesz kleyden vnd halten. Bey nechstgemelter straff.

Wie in gleichem auch die Schneider, so offt sie wider diese Ordnung handeln, vnd hierinnen verbottene Kleydung verfertigen wuerden, mit in verleibter straff, so wol als die jenigen, so es bey jhnen bestellen, einem Erbarn Rath verfallen seyn sollen.

Die Weibs Personen, vnd Deren Kleydung vnd Geschmack, Belangend

Es sol kein Weibs Person oder Jungfraw einigen Rock, Hosaecken oder Schauben, von gueldin oder silbern Tuch, noch auch von gantzen Sammat, antragen. Dergleichen auch, an vnd auff jren Kleydungen einig Perlin, gueldin oder silbern gesticks oder gesteps nicht anhaben, oder machen lassen. Bey straff zehen Guelden.

Es moegen aber die jenige Weibs Personen, so von den Erbarn Geschlechten seynd, Damaste, Atlase, vnd andere dergleichen seydene Roeck vnd Hosaecken, doch durch ausz ohne Leysten, vnverbraemt, vnd vngestept, wol antragen. Andere seydene, von Schamlot vnd dergleichen, Hosaecken, Roeck oder Sockeneyen aber, moegen sie mit drey eln Sammat, oder fuenff Leysten von seydenem Zeug, deren jede ein viertheil einer Elen hoch seyn sol, belegen. Auch die Leiblein, ausserhalb gueldenen vnnd silbernen schnueren, mit allem andern Zeug verbraemen.

Sie moegen auch gueldene Haarhauben, vnd gueldene Ketten antragen: Doch sollen der Weiber Ketten, so sie auff einmal antragen werden, nicht vber hundert Kronen, vnd der Jungfrawen Ketten, nicht vber viertzig Kronen, werth seyn.

Deszgleichen moegen sie auch gueldene Ringe, doch auff einmal nicht mehr als sechs, sampt einem zimlichen (B) Halsz Kleynot, vnd Perlin schnuer, wie auch ein par gueldene Armband, welche doch vber dreyssig, oder auffs hoechst viertzig Kronen, vnd nicht darueber, werth seyn, antragen. Alles bey straff, von jedem vorgemeldten stueck, fuenff Guelden.

Was sonsten anderer Namhaffter Buerger, auch der Rathsfreunden, vnd eines Erbarn Raths vertrawter, fuernemmer Cantzley verwandter Diener Hausfrawen vnd Toechter belangen thut, denen sol aller Sammat, Damast, Atlasz, seyden Schamlot, vnd dergleichen Zeug, zu Roecken oder Schauben, verbotten: Sonst aber aller anderer Gewandt (doch durchgehends ohn Sammat, ohne Belegen, auch ohne gesticks oder gesteps) deszgleichen sammete Koeller, vnd seydene (doch keine sammete, Niderlaendische Gaffa, Floret, vnd seyden Triebs) Leiblin, anzutragen erlaubt seyn. Obgemelte Weibs Personen, sollen auch keinen beschlagenen Guertel vber viertzig guelden werth, Auch auff einmahl nich mehr, als vier gueldene Ring, vnd dann Paternoester oder Corallenschnuer, vngefaehrlich zehen guelden werth, deren Toechter aber, kein perlin Baendlein, vber viertzig guelden werth, aufftragen. Die gantz silberne verguelte Guertel aber, wie auch die gueldene Ketten, Halskleynot, gueldene Haarhauben, verguelte Messerscheiden, Auch die Wetzger vnd Beutel mit Perlen gesteckt, vnd verguelten knoepffen, etc. sollen jnen zutragen gantz vnd gar verbotten seyn. Doch moegen sie silberne beschlagene Leibguertel vnd Messerscheiden, gantz weisz, auch auff jhren Beuteln ein halb dutzend silberne Knoepff ohngefaehr, wie auch jhre Toechter Haarlocken wol antragen. Es moegen nechstberuehrte Weibs Personen jre Sockeneyen* mit doppel Taffet, oder Atlasen Leisten, deren drey gleiche, jede ein viertheil (einer eln hoch, oder ein breite, vnd zwo schmahle, deren die breite drey viertheil hoch, vnd die zwo schmahlen, jede ein halb viertheil einer Eln hoch seye, vmblegen, vnd ob sie woellen, mit doppel Taffet vberstuertzen, Auch jre Leiblin, mit drey viertheil einer Eln Sammat, verbraemen. Alles, von jedem stueck insonderheit, bey straff zehen Guelden. So viel dann anderer fuernemmen Kraemer, oder *Notarien, Procuratorn,* vnd deren, so ungefaehrlich dessen Standts, Wesen vnd Herkommens seyn, Weiber vnd Toechter anlangen thut, Denselbigen sol kein seydener Zeug, zu Roecken oder Sockeneyen, zugelassen, sondern von gemeinem Schamlot, Bursat, Grobgruen, wie auch sammete Koeller, vnd damaste Leiblin zutragen, erlaubt seyn.

Jetzt gemelte Weibs Personen, moegen auch beschlagene Guertel, bisz in 25. oder 30. guelden werth, deszgleichen zween

* Grimm, Dwb. X, 1393. Weiblicher Ueberrock, aus slav. sukno-Wollengewand.

oder drey gueldine Ring auff einmal, Corallen Paternoester von 5. oder 6. guelden werth, seydene Beutel ohn silberne oder gueldine Borten, vnd ohn silberne Knoepff, auch sammete Messerscheiden vnd sammete Leibguertel, doch die beyde mit silber nit gantz beschlagen. So dann deren Toechter Perlin Baendlein, 30. guelden werth, auffs hoechst, auch Haarlocken, wol antragen. (Bij)

Sie moegen auch jhre Sockeneyen mit gemeinem Taffet, vnd dreyen Leisten, deren jede ein viertheil einer Eln hoch seye, belegen: Vnd, ob sie woellen, daran fuergehen lassen, auch jhre Leiblin mit einer halben Eln Sammat verbraemen. Bey straff, von jedem deren Stueck, acht Guelden.

Die Handwercks Weiber, gemeine Weinschaenckin, Kraemerin, vnnd andere, so mit schlechter Wahr vmbgehen, Auch diejenigen, so vngefaehrlich desselben Standts vnd Thuns seynd, belangendt, denen sollen die seydene Kleyder, vnnd schamlotte Roecke zutragen verbotten seyn: Doch moegen sie bursate Roeck wie auch arresse, grobgruene, vnd dergleichen Sockeneyen, vnnd dann sammete Koeller, auch Leiblein von Zendel dort, Taffet vnd Schamlot, wol antragen.

Es sol auch jetztgemelten Weibern, vnd jren Toechtern, einigen beschlagenen Guertel vber funfftzehen oder zwantzig Guelden werth, kein Perlin Baendlein vber zwantzig Guelden werth, kein silberne Messerscheid noch Leibguertel, kein Wetzger mit Gold oder Perlin gestickt, kein Corallen Paternoester, kein Schleyer mit gueldenen Leisten oder Aufflegern, kein Haarschnur vber anderthalb Guelden werth, auch keine Haarlocken zutragen gestattet werden.

Sie sollen auch hinfuero jre Sockeneyen mit burseten oder macheyern zwoen Leisten, einer breitten vnd schmalen, deren die eine drey viertheil Eln, Die andere aber ein halb viertheil, zc. Oder aber zwo gleiche, die ebenmaessige Hoehe haben, belegen, doch dieselbe mit seydenen Schnueren furters nicht zuvnterlegen. Wie sie dann auch jr Leiblein mit anderthalb viertheil einer Eln Sammat zuverbraemen, macht haben sollen. Vnd sol jhnen zween gueldene Ring auff einmal zutragen vnverbotten seyn. Alles bey straff, von jedem vorgesetzten stueck, sechs guelden.

Sonsten aber allen andern Weibern, vnnd deren Toechtern, auch Dienstmaegden, sol durchausz aller seydener Gewandt (auszgenommen gemeiner Taffet vnd Schamlott, welchen sie zu

einem Koeller oder Leiblein, mit eim viertheil einer Eln Sammat verbraemt, antragen moegen) verbotten seyn.

Deszgleichen sollen sie auch keinen Schleyer mit guelden Leisten, kein Perlin Baendlein, auffs hoechst zehen oder funfftzehen Guelden werth, kein Haarschnur vber einen halben guelden werth, aufftragen.

Ihre Roeck vnd Sockeneyen, sollen auffs hoechst Arres seyn, doch moegen sie die Sockeneyen mit einer burseten oder macheyern Leisten, vngefaehr einer halben Eln hoch, oder zwoen gespaltenen Leisten, belegen lassen.

Sie sollen auch keine gueldene oder silberne Borten, keine von silber beschlagene Guertel noch Messerscheiden, auch nicht mehr, als auff einmal einen gueldenen Ring, antragen. Bey straff von jedem gemelten stueck, zwen guelden. (Biij)

Die Kroesz belangend, sol es, in massen droben bey den Manspersonen vermeldet, so viel den Preisz vnd Hoehe anlangt, damit gehalten werden: Nemblich, desz ersten Standts Weibspersonen, mit Leinwat, Macherlohn vnnd allem, sechs guelden: Dem zweyten vnnd dritten Standt zu vier guelden: Den vierdten vnnd fuenfften Standts Weibern zu zween guelden werth.

Wie in gleichem die Auffschlaege betreffendt, ist den ersten vnd zweyten Standts Weibspersonen, dieselbe ein viertheil Eln hoch: Den dritten Standts Weibern ein halb viertheil einer Eln hoch zutragen erlaubt: Den andern aber allen gaentzlich verbotten.

Item, die Aufflaeger an den Schleyern, sollen den ersten vnd zweyten Standts Weibspersonen, dieselbe, wie sie es von Alters herbracht haben, Wie in gleichem dem dritten stand, doch hoeher nit als zu sechs guelden vngefaehrlich auffzutragen zugelassen, den andern allen aber gantz verbotten seyn.

Nach dem auch mit den Sammaten Hauben, vnd vbermaessigen Mardern vnd Zobeln Braemen, grosser Miszbrauch erwachsen: Als ist nothturfft halben angesehen worden, dasz dieselben maenniglichen, (ausserhalb denen Erbarn von den Geschlechten, vnnd den zweyten Standts Weibspersonen) zuverbieten seyen. Moegen demnach die im ersten Standt, dieselbe mit Zobel bescheidenlich: Die andern aber mit Mardern Braemen vnterfuottern.

Die dritten Stands Weibs Personen, moegen (ausserhalb Sammat) attlasze, damaste, seyden grobgruene, vnd dergleichen

Zeugs Hauben, mit Marderem Futter vnterlegt, wol aufftragen. Den vierdten Stands Weibs Personen, sollen Hauben von Taffet, Zendeldort, (vnnd nicht von hoeherem Zeug,) mit schlechten Mardern vnd Otter Braemen, zutragen erlaubt: Den fuenfften Standts aber, dieselbe, allein von Grobgruen vnnd dergleichen Zeug, ohne Mardern Futter, (welches jnen gantz vnd gar verbotten seyn sol,) sondern mit Ottern Braemen zutragen zugelassen seyn. Bey straff, von jedem gemelten stueck, dreyer guelden.

Vnd nach dem vorgemelte Weibs Personen, jetzt, wider alle Christliche Zucht vnd Erbarkeit, sehr im Brauch haben, dasz sie ohne Schleyer, schlecht in Hauben hin vnd wider in den Gassen, vnd auch auff dem Marckt vmbhergehen. Also, dasz man nicht wol wissen vnd vnterscheiden kan, welches Frauwen oder Jungfrauwen vnnd Maegden seyen: So wil vnnd gebeut ein Erbarer Rath ernstlich, dasz hinfuero die Weibs Personen, wann sie zu Gassen vnd Strassen gehen woellen, jhre Schleyer auffhaben, vnd die Jungfrauwen vnd Dienstmaegd jhrem Standt nach gemaesz sich tragen, vnd auszgehen sollen. Bey straff eines guelden.

Die Beltzen Futter Belangendt

Dje gantze Mardern Futter moegen allein die vom Adel, *Doctores,* vnd die Erbarn von Geschlechten, so Schoepffen vnd Raths Personen sind, vnd deren Weiber. Aber Marderkeln Futter moegen nit allein obgemelte Personen, sondern auch alle andere Erbarn von Geschlechten vnd jre Weiber antragen.

Sonsten andere gemeine Futer mag ein jeder, nachdem er zubezahlen vermag, anmachen lassen.

Hochzeit Ordnung

Nachdem auch im Jar der mindern Zahl Siebentzig vnd Sechs, eine Ordnung der Hochzeiten halben gemacht, inn welcher damals vor gut angesehen worden, dasz in geschenckten vnd vngeschenckten Hochzeiten, mit Laden vnnd Speiszen, gleichheit gehalten wuerde: So befindet doch nunmehr ein Erbarer Rath, ausz ehehafftem vnd sonderlichem Bedencken, auch jetziger zeit Gelegenheit nach, dasz dieselbe etwas *zulimitirn,* vnd wol zuaendern nothwendig seye.

Hat sich demnach volgender Ordnung verglicchen, vnd wil,

dasz hinfuero maenniglich in dieser Statt sich derselben nach gehorsamlich, bey vnnachlaessiger Entrichtung einverleibter straff, verhalte.

Das Laden Belangendt

Unnd so viel erstlich die freye: oder vngeschenckte Hochzeiten betrifft, dieweil dieselbe von Alters hero, bey niemands anders, als den Erbarn von den Geschlechten, auch etlichen andern Namhafften Buergern vnd statlichen Haendlern vnd Kauffleuten, im Brauch gewesen vnd noch: Leszt man es auch nachmals also, vnd bey jhrer Willkuehr verbleiben. Doch wil ein Erbar Rath, dasz solche von jhnen bescheidenlich *celebrirt,* vnd vber neun, oder auffs hoechst, zehen Tisch, darzu nicht erbetten werden. Bey straff, von jedem Tisch, fuenff guelden.

Sonsten zu geschenckten Hochzeiten, sol niemands weiter geladen werden, dann desz Breutigams vnd der Braut nechstgesipte Freunde, vnd deren Ehegemahlen, Als nemblich: In auffsteigender Linien, desz Breutgams vnd der Braut Rechte: oder Stiffvatter vnd Mutter, oder, wo sie nicht Eltern hetten, jhre Vormuender vnnd derselben Ehegemahlen. Deszgleichen jrer beyder Rechte: vnd Stiff: An Herrn vnd An Frauwen, zc. In absteigender Linien, desz Breutgams vnd der Braut (im fall die zuvor im Ehestand gewesen) Eheliche Kinder, sampt jhren Ehegemahlen, vnd Toechtern, zc. In der neben Linien, desz Breutgams vnd der Braut Brueder, Schwestern, auch derselben Kinder, sampt jren Ehegemahlen, oder derselben Witwern vnd Witwinnen, Deszgleichen jhres Vatters vnd Mutter Brueder vnd Schwester, auch derselben Kinder, Soehne vnd Toechter, als die mit jhnen leibliche rechte oder einhalb geschwisterte Kinder sind, sampt deren Ehegemahlen, auch diejenigen, so mit jrem Vatter vnd Mutter Geschwister Kinder gewesen, oder noch sind, sampt deren Ehegemahlen, vnd nicht weiter, laden. (C)

Vonwegen der Schwaegerschafft, mag der Breutgam seiner vorigen Hauszfrawen Brueder vnd Schwestern, sampt deren Ehegemahlen, auch derselbigen Kinder vnd deren Ehegemahlen, vnnd nicht weiter, laden: Gleichergestalt auch die Braut thun mag. Aber derselben Schwaeger, das ist, Schwagers Schwaeger, sollen, als vnverwandte Personen, gar nicht geladen werden. Alles bey straff, von jeder Person, so jetztgemelter

Ordnung zuwider geladen wirdt, dreyer guelden vnnachlaeszlich zubezahlen.

Doch moegen sie zu den Gesiepten, acht par, das ist, sechszehen vnverwandte Personen, vnd nit drueber laden. Were es aber sach, dasz zwey zur Ehe grieffen, die beyderseits keine, oder vber sechs paar, verwandter Personen nicht hetten, denen sol erlaubt seyn, dasz jeder theil noch sechs paar Volcks, das ist, dem Breutgam zwoelff, vnd der Braut zwoelff Personen, ob sie woellen, laden moegen, vnd nicht drueber, bey Peen, von jeder Person, eines guelden.

Vnd wil hiemit ein Erbarer Rath keinem mehr (wie etwan biszhero vielfaltiger weisz durch ansuchung geschehen) dann obstehet, zugelassen haben.

So sollen auch von den Jungen Gesellen, so nit verwandt sind, wie obsteht, mehr nicht als acht Personen geladen werden, Doch, dasz ein jeder derselben vnverwandten, achtzehen, (bisz in zwantzig) Jahre, vnnd nicht darunter, alt sey. Deszgleichen von Jungfrawen, so nit verwand sind, auch acht Personen, deren ein jede vber fuenffzehen Jahr, vnd nicht darunter, alt seye, geladen werden. Bey Peen, von jeder Person, eines guelden, es erscheine gleich dieselbige geladene Person oder nicht.

Zum andern, So sollen hinfuero, weder zu geschenckter noch vngeschenckter Hochzeit nicht mehr als drey Jmbs, Als nemblich: Den ersten Tag zwey, vnnd den andern Tag das Nacht Imbs, gehalten werden.

Doch, so frembde auszlaendische Personen zur Hochzeit geladen weren, die moegen den ersten Vorabend, deszgleichen den zweyten Tag zu Mittag allein, sampt der Braut vnd Breutgams Eltern vnnd Geschwisterten, in der Braut oder des Breutgams, oder deren Eltern, oder Verwandten Behaussungen, oder an dem Orth, da die Hochzeit gehalten wirdt, jhre Imbs nemmen, vnnd sol ferner niemands darzu geladen werden. Wer solches vbertretten wird, sol von jedem Imbs zehen guelden zur straffe vnnachlaeszlich bezahlen.

Es sollen auch die Gartenfahrten, deszgleichen der Jungen Gesellen vmblauffen auff den Gassen mit den Spielleuten in die Wirthshaeuser, auch nach gehaltener Hochzeit das Nach Zechen, spatzieren, vnnd auff die Hoefe vnd Doerffer vmbhergehen oder fahren, gantz vnd gar abgestellt vnd verbotten seyn, bey der vorgemelten straffe der zehen guelden. (Cij)

Zum dritten, die Spielleut belangendt, sol allein den Erbarn von den Geschlechten, bey jhrem alten vblichen Gebrauch vnd Herkommen zubleiben, frey stehen: Aber allen andern, wes Standts vnd Wesen sie auch seyen, sol auffs hoechst drey Spielmaenner zuhaben, erlaubt seyn, welchen auch, einem jeden insonderheit, mehr nicht, als von jedem Imbs ein halber guelden gegeben werden sol. Wer solches vberfuehr, sol von jedem Spielmann drey guelden zu busz verfallen seyn.

Zum vierdten, die Braeutsuppen belangendt, sollen dieselben bey maenniglichen abgestellt, vnnd auszzugeben gantz vnd gar verbotten seyn, bey straff, von jeder Suppen, eines guelden, den ein jeder, beyde der Geber vnnd Nemmer, erlegen sollen. Es hette dann der Breutgam oder die Braut eine oder mehr verwandte Personen, die Schwachheit halben nicht erscheinen koendten, denen mag man, nach eines jeden Gelegenheit, ein Essen zu Hausz, wie herkommen, schicken.

Zum fuenfften, sollen auch hinfuero die Kuechenmeister vnd Koechinne, auch die Kammerfrawen, vnd andere, so zur Hochzeit dienen, kein sonderlich Geloch oder Gasterey in jhren oder andern Haeusern halten, sondern mit jhrem Lohn, vnnd Essen, so jhnen zur Hochzeit gegeben wirdt, zufrieden seyn. Bey straff fuenff guelden. Vnnd sol jhnen nicht mehr, wie es zeithero sehr miszbraeuchlich geschehen, Tischweise, sondern zu grossen vnnd Herren Hochzeiten, nemblich dem Kuechenmeister fuenff oder sechs guelden, der Koechin gleich so viel, vnd der Kammerfrawen zween guelden, vor jhre Muehe vnnd Arbeit zu Lohn gegeben werden: Aber zu den gemeinen schlechten Hochzeiten halb soviel.

Zum sechsten, die Tischdiener vnd Thorhueter belangend, sol einem jeden einen Tag vier albus zu Lohn, vnd ferner kein Brot noch Wein, oder ander Essenspeisz (wie biszhero vielfaltig geschehen) heimzutragen gegeben werden. Alles bey straff eines guelden, welchen der Nemmer so wol, als der Geber verwirckt haben sol.

Zum siebenden, so Schenckhochzeiten gehalten, vnd Becken auffgesetzt werden, moegen die Verwandten nach jhren Ehren vnd Wolgefallen, wie viel sie woellen, Aber die Verwandten sollen das paar Eheleut, nicht mehr, dann einen Goldtguelden schencken. Bey straff fuenff guelden.

Die Junge Gesellen sollen, ein jeder ein halbe Kronen oder

zwoelff Patzen, vnd die Jungfrauwen acht Patzen, vnd nicht mehr schencken, bey straff zweyer guelden.

Zum achten, die Oertenhochzeiten belangendt, nach dem dieselbe den Hochzeitleuten, bevor ab den geringern, also bequemlich vnd gut, biszhero vnverbotten gewesen. So leszt ein Erbarer Rath dieselbe nachmals passirn. Mag demnach ein jeder, nach seiner Gelegenheit, einem Wirth oder Gasthalter, auff eine, zwo, oder drey (Ciij) Mahlzeiten, vnd nicht drueber, seine Gaeste vnnd Hochzeitleut auffdingen. Doch sol er sich mit dem Laden, Gartenfaehrten, Spielleuten, vnd Essen geben, vorgeschriebener Ordnung nach gemaesz verhalten.

Zum neundten, dieweil jetziger schwerer vnd thewrer Zeit halben, bey dem gemeinen Mann sehr wol vnnd nuetzlich auffkommen, dasz jhrer etwan zwen, drey, vier oder mehr paar Volcks, zugleich mit einander zwar zur Kirchen gehen, aber nuhrend von einem derselbigen die Hochzeit allein gehalten wirdt, Da dann derselbige Haupt Breutgam seinen Vortheil, nicht ohne nachtheil der andern, mit allerhandt ein: vnd ausz dingen, erseihet vnd gebrauchet, (vber welches dann viel Klagens biszhero angehoeret.) So ist demnach eines Erbarn Raths gaentzlicher Will vnnd Meynung, dasz hinfurthan jedes paar, so mit einem andern zur Kirchen gehet, aber zu keinem Imbs erscheinet, einen Reichsthaler, vnnd nicht drueber, dem Haupt Breutgam zuerlegen, schueldig seyn sol. Im fall aber jemands auch zu den dreyen zugelassenen Imbsen erschiene, doch kein Vnterschenck hielte, sol von jhme vier guelden auffs hoechst, mit Schenckung vnnd allem, vnwegerlichen entrichtet werden. So aber Vnterschencken gehalten, Gebratenes vnnd andere dem zugehoerige ding, mit gegeben wuerden, sol der Haupt Breutgam von jedem derselben paar, sechs guelden inn allem, vnnd nicht mehr, fordern vnnd zugewarten haben. Alles bey straff, von jedem vbertrettenem stueck, zwen guelden.

Vnnd letzlichen, So viel die Zusammenkunfft zun Hochzeitmahlzeiten anlangen thut, dieweil biszhero ein vberausz verdriezliche Vnordnung darausz entstanden vnnd vergangen, nicht ohne sonderliche Verhindernuesz aller anderer der Hochzeit Geschefften, darueber sich dann auch etwan die frembde geladene Personen mit Vnwillen verwundern muessen: So wil demnach ein Erbar Rath hiemit ernstlich befohlen haben, dasz auff allen, hohen vnd nidrigen Standts, Hochzeiten, hinfurthan die Mittags Imbs vmb eylff, vnnd die Abend Imbs zu sieben

vhrn, auffs laengst, angefangen, vnd deren keins vber die dritte stunde erstrecket noch gehalten werden sol. Bey straff, von jedem Imbs, zwen guelden, welche der Breutgam zuerlegen schueldig seyn sol.

So offt auch jemands der Hochzeit Gaeste, vber ein viertheil nach zwoelff vhrn desz Nachts, im Tantzhausz, oder an dem Orth, inn welchem die Hochzeit gehalten wirdt, erfunden wuerde, Sol derselbe jedesmahl mit einem halben guelden verbuessen.

Die Andern Grossen Gastereyen Belangendt

Nachdem nicht allein bey Hochzeiten, sondern auch in andern Gastereyen, allerley vberflusz (vnangesehen, dasz alles, was der Mensch geleben sol, zu diesen beschwerlichen Zeiten in hohem preisz ist) geuebt vnd gebraucht wird, vnd je einer vber den andern seyn, vnd etwan der vnvermoeglicher den vermoeglichern es nachthun woellen, zu zeiten auch nicht zu geringem jrem selbstverderben: So ordnet vnd wil ein Erbarer Rath, dasz hinfuero nicht allein auff Hochzeiten vnd Weinkauffen, sondern auch solchen Gastmahlzeiten, auff ein jedes Imbs nit vber drey Trachten, den Keesz darein gerechnet, gegeben, vnd dabey vber zwey Neben Gericht oder Beytrachten von Fleisch oder Fisch, auffgesetzt werden sollen, Ausserhalb bey dem Keesz, mag man Gebackens, Obsz, vnd dergleichen ding mit auffsetzen. Doch, so etwan stattliche vnd Herrn Hochzeiten gehalten wuerden, mag man zu jeden vorgesetzten Trachten drey oder vier Nebengericht, vnd mehr nicht, vorsetzen.

Vnd sollen hiemit die Collatzien vnd Schlafftruenck nach dem Nachtessen, dieweil dieselbe ein lauterer vnnuetzer, schaedlicher vnnd suendlicher vberflusz seynd, gar abgeschafft seyn, vnd durchgehends niemands mehr gestattet werden. Bey straff von jedem Mahl zehen guelden. Doch ob etwan einer frembde Auszlaendische ansehenliche Personen zu gast halten woelte, dem sol hiedurch vnbenommen seyn, dieselbe etwas reichlicher, nach gelegenheit derselben Personen, zutractirn.

Letzlich, die Beylager belangend, dieweil bey denselben biszhero auch zuuiel vnnoetiger vnd vbermaessiger Unkosten vnd Pracht, Auch von den geringen Stands Personen, mit grossem nachtheil vnd schaden jhrer selbsten, angewendet, vnnd gespueret worden. So wil ein Erbar Rath von maenniglichen dieselben mit masz vnd groesserer bescheidenheit hinfurter ge-

halten haben. Vnd dieweil auch jeder ausz vorgesatzter Ordnung leichtlich abnemmen kan, was vnd wieviel jm (seinem standt nach) hierinnen vnverweiszlich zuthun gebuere, vnd wol anstehe, wird er sich selbst darnach zuverhalten wissen, Oder aber eines Erbarn Raths vnnachlaessiger straff (welche jm gedachter ein Erbarer Rath hiemit ausztruecklich vorbehalten haben wil) der Vbertrettung halben, alsz dann gewertig seyn.

Es sollen auch die Braeutschuhe, so die zeithero, ohne sonderlichen nutz, vnd nur allein zum Pracht, von Sammat, mit Goldt, Silber, Seyden vnnd Perlin gestickt vnd zugerichtet worden, gaentzlich abgeschafft, vnd kein par vber eines Guelden werth gemacht noch getragen werden, bey straff dreyer Guelden, damit, so wol der sie macht, als der sie betstellt vnd antraegt, verfallen seyn sol.

Die Kindbeth Belangendt

Setzt ein Erbar Rath, dasz ein jede Kindbetterin zu dem Kind Tauff, vber diejenigen, so bey jhr in Kindsnoehten gewesen weren, vnd die Gevatterin, oder (D) desz Gevattern Hauszfrawen, nit mehr als jres Hauszwirths vnd jr gesipte Weibs Personen, wie hievor in der Hochzeit Ordnung vermeldet wird, bitten sol. Hette aber die Kindbetterin oder jr Hauszwirth wenig oder keine gesipte Freunde allhie, so sol sie vber die Gevatterin, vnd die Personen, so bey jhr inn Kindsnoehten gewesen weren, nicht mehr als zwoelff Frawen Personen zu der Kind Tauff bitten vnnd laden. Bey straff eines Gulden, von jeder Person, so hierueber gebetten wird.

Doch wil ein Erbar Rath, die Kindbetterin von den Erbarn Geschlechten, hiemit nit verstanden, noch jnen an jrem alten Gebrauch vnd Herkommen jchtwas benommen haben, Versiehet sich aber doch, ein jede derselbigen werde sich hierinnen also verhalten, damit jnen selbst kein verweisz vnd nachtheil darausz entstehe: Daher dann ein Erbarer Rath moechte vervrsacht werden, ein billiches Einsehen auch zuhaben.

Ferner, welcher, oder welche ein Kind ausz der H. Tauff zuheben gebetten wird, vnd der, oder die, desz Kinds Vatter oder Mutter, oder sonst mit siepschafft, wie vorstehet, verwandt were, die moegen dem Tauffpettern oder Gaden, nach jrem gefallen Schenck thun. Aber die den Tauffpettern oder Gaden, oder dessen Vatter oder Mutter solcher gestalt nicht verwandt,

sollen vber zween guelden in allem nicht schencken. Bey straff vier Guelden.

Nachdem auch in den Kindbetten biszhero allerley vnnoehtiger vberflusz, so wol in anstellung der Mahlzeiten, als auch mit dem geschmuck der Gevatterin Kuchen (wie solche im brauch gewesen) getrieben worden. Als wil ein Erbar Rath gemelten vberflusz (so viel die Kuchen belangt) nunmehr gentzlich abseschafft, Vnd dann, soviel die Mahlzeiten betrifft, wofern es der Kindbetterin gelegenheit seyn wuerde, nach verrichter Tauff, den jenigen Weibs Personen, so jhr in Kindsnoehten beygewohnet, sampt der Gevatterin, auch denen, welche jr mit naher siepschafft zugethan seynd, ein zimliche, jrem stand gemesz, Mahlzeit zugeben, Die Vbermasz hiemit ernstlich verbotten haben. Vnd sollen hiedurch die Mahlzeiten, welche die Kindbetterin nach den vier Wochen zuhalten gepflogen, wie auch die Mannszgelach in den Kindbetten, durchgehends bey allen stands Personen, weder vor oder nach den vier Wochen zuhalten gantz vnd gar eingestelt vnd verbotten seyn. Bey straff, wer darwider handeln wuerde, von jeder Person zweyer Guelden. Doch den Maanspersonen die Kindschenck auff den Zunfftstuben, altem gebrauch nach, zuhalten vnd zubesuchen vnbenommen, doch dasz sie nach gehaltener Zech mit den Gevattern nicht heimgehen, vnnd eine newe Zech anfangen. Bey vorgemelter straff, von jeder Personen.

Als auch in dieser Statt von alters gebraeuchlich gewesen, dasz der Gevatter, oder Gevatterin, sein Tauff Paten, wann der seine fuenff, oder nach gelegenheit, sechs Jahr erreicht, ein besonder Paten Roecklein machen, vnd damit verehren lassen. Solchs aber nu ein zeit hero, bey jedermaenniglich in einen solchen miszbrauch erwachsen, vnd dahin gerahten, dasz man es numehr fuer eine (gleich wol boese) gewonheit achten, vnd ins gemein gleichsam fuer ein schuldigkeit halten thut, dasz nemlich der Gevatter oder Gevatterin, seinen Tauff Paten mit einer gantzen Kleidung, von fusz auff, auszstaffiren lassen muesse. Darinn dann je einer vor dem andern gesehen seyn, vnd biszweilen zu jrem selbst mercklichen schaden, beuor thun woellen. Ausz welcher vnordnung vnd miszbrauch erfolgt, dasz Christliche hertzen, welche die Gevattern bitten sollen, so wol auch die zu solchem Ehrnwerck etwan zeitlich erbetten werden, an statt dessen, so sie sich, als eines Christlichen Wercks billich erfrewen sollen, etwan dagegen entsetzen

muessen. So wil offternannter ein Erbar Rath solchen miszbrauch hiermit auch abgeschafft, vnnd solche Kleydung gaentzlich verbotten haben, Jedoch gleichwol den Gevattern oder Gevatterin vnbenommen, sein Tauffpaten, neben obgemelter zugelassener schenckung, gleich jnnerhalb vier Wochen nach der Tauff mit einem hembdlein, wie von alters herkommen, zuverehren, welchs vber zwen, oder zum hoechsten drey guelden nit werth seyn sol. Bey straff, wer dieses vberfahren wuerde, zehen guelden, die, so wol der Gevatter, als auch der Schneider, so die Kleyder, wie obgemelt, machen wuerde, vnnachlaeszlich zuentrichten verfallen seyn sollen.

Vnd sol diese Ordnung nach verscheinung dreyer Monat, von Publicirung derselben, angehen, vnd fuerthers, bisz auff eines Erbarn Raths ferner Verordnung, also gehalten werden.

—*Conclusum in Senatu,* Donnerstags, den 15. *Decembris,* Anno 1597.

THE DIAMOND MINING INDUSTRY OF SOUTH AFRICA

RUFUS MATHER BAGG

INTRODUCTION

The discovery in 1866 of a 21¼ carat diamond by a Dutch farmer, Schalk Van Niekerk, which was being used as a plaything by some children at Hopetown, was an epoch making event in the economic development of South Africa. Niekerk gave it to a trader O'Reilly who took it to Cape Town for inspection. Here a French jeweller pronounced it a diamond of first quality and priced it at $2,500. This gem was sold and the proceeds honestly divided with the former owner. Two years later Niekerk bought a second stone from a Hottentot for $2,000 which weighed 83½ carats and this he immediately sold for $56,000. It was later known as the "Star of the South" and is now in possession of the Countess of Dudley.

These discoveries led to the immediate rush of diamond diggers in large numbers searching for stones in the Vaal river gravels, which, if found, could change the status of the owner in one day from poverty to riches. In no other form of mining is the element of chance so remarkable or rewards so instantaneous, but on the other hand no other kind of mining presents a greater gambler's luck and the digger frequently remains in poverty, using the funds of each random discovery to finance his further explorations.

The writer met some of these miners washing gravel 40 miles west of Kimberley at Longlands on the Vaal river and they were most interesting characters who had experienced the ups and downs of life with all its hazards.

KIMBERLEY

No one thinks of diamonds without a vision of Kimberley and this "City of Diamonds" owes its existence to diamond mining alone and upon this industry its entire future prosperity and life depends. Kimberley was a semi-arid plain of the high Karroo in 1867, but a cluster of miners tents in 1870

when the city was founded. Kimberley is a most interesting place to visit, but the greatest sight here and one of the unique sights of the world lies within five minutes walk of Market Square near the Post Office. This is the OLD KIMBERLEY MINE, the second largest diamond mine hole on earth, being exceeded only by the Premier 25 miles east of Pretoria, Transvaal province.

The famous Old Kimberley mine is now abandoned, but was dug to a depth of 3,601 feet. It covers an area of 38.19 acres and the perimeter measures 0.93 mile. There was no "Yellow Ground" at this volcanic pipe and the entire workings were in "Blue Ground" 800 feet thick. Below the blue comes a melaphyre, then a quartzite 800 feet thick resting upon a granite base through which the Kimberlite pipe erupted from a still greater depth. The bottom of the mine is filled with water up to 1300 feet from the surface and the crater walls have caved downward. Trees and brush are growing on the talus slopes. This pipe trends north and south, but with a width in this direction of 1,550 feet and an east and west axis of 1,500 feet the opening appears nearly circular.

The remarkable thing about the Old Kimberley mine was the high yield of diamonds per load which amounted to 30 carats per 100 loads.*

Low as this recovery might appear to be, it is nearly double that of most of the Kimberley pipes now being worked. In fact, so few diamonds occur in Kimberlite that it is only rarely a stone is found in *situ.*

This minute amount of diamond content may be better understood if you take a "ten carat" mine, which is quite a good mining proposition; the richness would be equal to 2 grams per 100 loads each weighing 1600 pounds, or *less than one twenty-two thousandths of one per cent.* This means one diamond, on the average, in 40 cubic feet of broken blue ground. Only three or four volcanic pipes are worked to-day within a radius of four miles at Kimberley, the more important being the Wesselton, Bulfontein and the Dutoitspan. We collected blue ground from the latter at a depth of 1350 feet, for the deeper mines are now being developed both by open pit and shaft methods. The mines of Kimberley and of the Premier,

* A *load,* the unit of measurement of South African diamond rock, represents 16 cubic feet of broken blue ground, roughly equal to 1,600 pounds.

400 miles northeast in the Transvaal, supply the bulk of the world's diamonds to-day, but the production could easily be expanded if trade demanded. A larger yield than $60,000,000 a year would lower the price and flood the market. The De Beers Consolidated not only controls the production, but they stabilize the price of diamonds to prevent a collapse of the industry.

The wealth taken from within an area of four square miles at Kimberley has exceeded one billion dollars in less than 50 years, a truly astonishing sum expended upon a luxury and not a necessity of life.

It is difficult to gain any idea of the magnitude of diamond mining operations from description. The great pulsator plant near the Wesselton mine pulverizes 11,000 tons of blue ground daily, uses nearly one million gallons of water for washing which comes from the Vaal river 17 miles distant. If only one diamond is recovered from three loads, which is perhaps a fair average, the day's run would furnish about 4,430 diamonds, but of very varied size and value.

Kimberley lies 647 miles north of Cape Town in the Orange Free State and is a city of 17,095 whites and 21,095 colored. It lies at an elevation of 4,018 feet and is wind swept by the dust storms of the Kalahari desert to the west, but has a fair rainfall in the wet season.

The city is irregularly laid out and like most mining camps the streets cross at all angles. The museum is rich in Bushman art relics, diamond exhibits and beautiful mineral specimens, but for a municipality which has produced such exceeding wealth the buildings are not imposing.

Kimberlite Pipes

The number of volcanic pipes and dikes of Kimberlite diamond bearing rock in South Africa is unknown for they are scattered over an enormous territory in groups from the Orange Free State southwest boundary, to Pretoria of the Transvaal and northward in isolated areas into the Belgian Congo. Many are so concealed by ages long surface weathering that they are discovered by accident, as where a few gems have weathered out at the surface of the pipe.

There are at least 60 such pipes in the vicinity of Kimberley which have broken through the red granite base, overlying

quartzites, slates, melaphyres and Dwyka shales above. They are without any orderly arrangement, occur in varying dimensions, shapes, and igneous rock composition; and what is more remarkable, these pipes differ in area downwards and pinch out into dike like extensions on one side as if occurring as a swelling in some original fissure. The Old Kimberley mine was nearly circular at the surface and nearly 1600 feet across, but with its axis trending north and south; at a depth of only 340 feet the pipe was an oval measuring 820 by 500 feet, but at 2,160 feet this had contracted to a width of 250 feet. At a still greater depth the pipe seemed to have moved bodily eastward for quite a distance and from this bottom working, had sent out a tongue-like dike in a north–northwest direction toward the St. Augustine mine, and this mine at 800 feet becomes a wide fissure striking toward the Old Kimberley pipe.

What was more surprising to me was the fact that even within one pipe diamonds differed from one end of the crater to the other, and in each pipe the diamonds are so different that an expert can tell at a glance from what mine a given gem has come. Nearly all the stones from the Dutoitspan mine are of a distinct yellow shade, but of very remarkable size. I saw one just recovered from the washing table in July 1929 that weighed 199½ carats*—a perfect octahedron crystal valued at $10,000 uncut.

The crystals from the South African mines are nearly all octahedrons, but with modified surfaces, bevelled edges, curved or fluted as well as etched by tetrahedral depressions.

Dodecahedral and other isometric forms occur, but they are not as abundant as the octahedron. Jagersfontein stones are usually cleavage fragments, Koffyfontein gems are nearly pure white, Voorspoed diamonds are dull and very hard to cut, while those from the Wesselton are cold blue-white crystals of purest water, but of small size and usually less than 2 or 3 carats weight.

Kimberley produces stones weighing several hundred carats and, of the million dollars worth of freshly collected diamonds from the Kimberley pipes, I noted a good many weighing from 10 to 30 carats each.

The largest diamond in the world, however, came from the

* A carat = 0.2 gram or about 3.1 grains.

Premier mine in the Transvaal. This immense diamond weighed uncut 3,035¾ carats, or 1.37 pounds avoirdupois, but it was only a cleavage piece from a still greater octahedron, whose adjoining parts have never been discovered. The mine superintendent told me that, when they found this diamond, he threw it over the railroad track feeling certain that such an immense crystal could only be a chunk of glassy quartz.

The Kimberley pipes and similar diamond bearing igneous intrusions broke through an enormous thickness of overlying granite and sedimentary strata with explosive outpourings which continued through a long period in late Cretaceous time. Many of these deep-seated basic Peridotites now called Kimberlites are connected at great depths by fissure fillings of the same igneous magmas, but the igneous rocks vary widely in composition and in mineral content.

The Kimberlite is an ultra-basic rock containing enough minerals and gem crystals to fill a museum, but the more abundant and best crystallized types include Olivine, Chrome Diopside which is often in large crystals, Garnets, often so abundant in masses as to constitute Eclogite rock with scarcely any other mineral present, Enstatite, Phlogopite, Magnetite, Spinel, Sapphire, Cyanite, Hornblende, and of course, the *Diamond.*

The huge green diopside crystals we found at the Wesselton mine seemed translucent enough to be gems and the garnets look like true red rubies. Many other minerals occur both secondary and original, and the pyrite crystals caught on the washing tables are very perfect and of fair size.

The rock fragments in the Blue Kimberlite seem to include granite and granite gneiss, schist, slate, shale, quartzite, porphyry and basalt. Serpentine is present and the limestone infilling in one of the Kimberley pipes is very difficult to explain.

The wedge-shaped felsitic porphyry mass at the Premier mine is tapering downward and will soon be entirely removed as the pipe comes together at each end around this "horse" which must have fallen in from above during the explosive eruptions of the Kimberlite. It is this brecciation of the infilling igneous rock which makes decomposition so rapid and which assists in crushing without destruction of the diamond.

Occurrence of Diamonds in South Africa

It is safe to assume that the original home of all African diamonds found in river gravels all over the Union, the sea coast, and in volcanic brecciated pipe fillings in widely separated areas, came from igneous magmas lifted by explosive forces from great depths within the earth's crust. The diamond looks as if it were an accidental occurrence rather than an original primary mineral of the ultra basic Kimberlite.

The alluvial stones below the Premier were traced back to the old crater walls of the pipe and diamonds far from these interior pipes show stream abrasion and water wear. While the bulk of South African stones come from the high Karroo plateau and in true igneous eruptive pipes, gems have been found in the Witwatersrand gold bearing conglomerates of Pre-Cambrian age, in the Forest Sandstone of Upper Triassic time, most abundantly in the late Cretaceous eruptions, but in the Tertiary and Recent formations in river gravels, sandstones and coastal deposits, especially on the west coast as far northward as Port Nolloth and on islands off shore. Each year seems to add new discoveries and the Namaqualand surface diamonds of surprising beauty and size occur in such abundance as to prove a menace to diamond crushing at the great interior pipe centers. I saw these cut at Cape Town and they were remarkably free from flaws and inclusions, and the color was unsurpassed.

Premier Pipe, Transvaal

While the diamond mining center is and probably will always be around Kimberley in the Orange Free State, the largest and richest diamond mine in the world lies 25 miles east of Pretoria, the administrative capital of the Union with a total population of white and colored of 100,000. Pretoria is a wonderful city with beautiful buildings, museum, zoological gardens and parks; with its suburbs included, it covers an area of 40 square miles. The Government buildings cost over five million dollars and are so situated that a most commanding view of the entire region can be had from the central archways and platform steps.

Pretoria does not depend entirely upon diamond mining as does Kimberley farther south, but the biggest diamond mine on

earth only 25 miles away must have had some influence upon the growth of the city. It is worth a trip to Pretoria to stand at the edge of this gigantic man-made surface opening, worked for 27 years, covering 78 acres and dug to a depth of 650 feet, with workings in 50 foot benches. The general grade of the mine is worked at 1½ per cent, the fall being from the South to the North end. The broken ground is hauled up to the reduction plant crushers 3000 feet on a grade of one in five feet.

The Premier pipe is oval, with the longer axis trending northeast; it is about 2,000 feet long and 1500 feet in width, or roughly one-half mile by a quarter of a mile, and from the rim presents an awe-inspiring spectacle. The size of this gem-mining industry at the Premier can be judged when you learn that 5,000 natives and 570 white men are employed throughout the company's works. The output up to August 31, 1928 amounted to 121,119,541 loads of ground, which have been treated by the combined gears, and from which have been recovered diamonds weighing 27,020,773 carats.

From the way the present walls of the pipe stand up it is known that this open pit method of mining at the Premier can be followed downward to a depth of 1000 to 1200 feet, and nine bore holes from 300 to 1001 feet still continue in diamond bearing rock. This depth of workings will represent 400,000,000 loads of ground of 16 cubic feet each and, calculated on the present rate of production of 12,000,000 loads per annum, will make it possible to dig in this pipe for 34 years without resorting to shaft and tunnel mining methods.

Recovery of Diamonds

Alluvial washings present no difficulty in diamond recovery, but they do involve treatment of enormous tonnage for carat extraction. After washing in revolving pans with walking arms for cleaning mud and sediment away, the pebble gravel deposit left behind is spread out on burlap-covered tables, scrapers are run over the wash and the brilliant glistening gem stones are picked out by hand.

Dams are constructed along the river basin, waters controlled by selective intake, gravel raised in benches and in zones from the river bed and, if these rolled materials have not already been gone over, they may yield some beautiful

stones which are of very superior quality and, when of large size, far surpass the pipe recovered stones in money value.

In mining diamonds from Kimberlite the process is involved and we wonder how a tiny gem stone can go through the blasting process from the bench floor, be hauled in cable cars like ordinary rock to the crusher, gyratory, washing pan, sizing grizzleys, and then be floated out on grease tables to be caught in vaseline while the broken pebbly wash material rushes on to the slime basins below the jigs.

The rolls are huge affairs, several feet in diameter, but hung on springs, they are sufficiently elastic to permit the hard diamond to pass uninjured while they are tough and resistant enough to break up the blue ground containing the occasional gem stone.

After crushing, washing, sorting and sizing and the catching of the stones on the vaseline coating, the grease is melted and the diamonds are carried to a sorting table where the gems are graded, sorted by color, freedom from flaw, and passed to the office for lapidary cutting.

Other Occurrences

The discovery in 1908 of diamonds in sands of the Luderitz Bay coast is truly remarkable because it is so far removed from known volcanic pipes of the high interior Karroo.

This discovery has been pushed still farther northward up to Conception Bay and to Port Nolloth as well as to islands off the shore.

Origin of the Diamond

It would appear to be a simple matter to explain the origin of diamonds when they are found in *situ* in basic igneous rocks in volcanic necks where explosive eruptions have lifted them within reach of surface mining, but the problem is so complex that just how and where these brilliant carbon crystallizations originated and at what depths within the crust is still unknown. It is not certain that they actually belong to the altered Kimberlite basic rock types where found for they must be considered occasional, and not uniformly essential primary rock forming minerals of these unique blue masses. Surely in one pipe the diamonds should be similar in crystallization, color, form,

and abundance, but this is not the case. Not only is each pipe different in every way from its adjacent group, but the diamonds in each are so distinct that they can be recognized at once as occurring in a given pipe blue ground.

Artificial production of the diamond ought to shed light on its origin, but diamonds of large size and of commercial value have not yet been formed by laboratory methods. Many scientists have worked for years upon this problem and several have actually been able to crystallize tiny diamond crystals in molten steel, lead, silver and carbon bearing solutions when the fused mass is subjected to high pressure and sudden cooling. There is no agreement yet upon just how these peculiar gem stones, the hardest substance on earth, came into existence in beautiful, transparent, colorless minerals while the counterpart carbon is as black and opaque as coal, lusterless and the softest substance known. Graphite is pure carbon, but it is as different from pure carbon in the diamond as black is from white.

Pressure under exceeding depths is a most important factor, but just under what conditions and in what state the carbon occurs is not yet positively known. There is no substance on earth that can match the diamond in hardness and some other peculiar physical properties which, with its unrivalled beauty, make this mineral the queen of precious stones and the most costly of all gems.

THE GLOVER BLUFF STRUCTURE, A DISTURBED AREA IN THE PALEOZOICS OF WISCONSIN

GEORGE L. EKERN AND F. T. THWAITES

Introduction. Glover Bluff is situated in the northwestern corner of Marquette County, Wisconsin, about 75 miles north of Madison and about two and a half miles west of U. S. Highway 51 near Liberty Bluff station. The exact location is the southwest quarter of Section 3, Township 17 North, Range 8 East. That the bluff consists of highly disturbed Paleozoic strata has been recognized for many years, but no detailed study was made until 1928 when the problem was assigned to the senior author for a Bachelor thesis at the University of Wisconsin. The following account has been rewritten by the junior author from this thesis.[1]

Previous investigations. Glover Bluff was not visited by Irving,[2] for, although he mentioned it, he located the hill in the wrong section both in text and on the atlas sheet. The first geologist who is known to have reached the bluff was Alden[3] who observed the disturbed layers in a portion of the area. Later W. O. Hotchkiss, E. O. Ulrich, Lawrence Martin, E. F. Bean, the junior author, and other geologists made brief visits to the locality.

Nomenclature. When the region adjacent to the bluff was first settled, a man named Glover started to burn lime on a bluff about two miles south of west from the district here under discussion. Irving called this other elevation "Glover and Merriman's Lime Bluff", but it is now known as Bald Bluff. It is said that, because the dolomite strata are lower and more readily accessible in the eastern locality, Glover later moved his operations. Although the bluff here discussed is called "Lime

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[1] Ekern, G. L., The geologic structure of Glovers Bluff, Marquette County, Wisconsin, Unpublished thesis, copies in libraries of University of Wisconsin and Wisconsin Geological and Natural History Survey.

[2] Irving, R. D., Geology of central Wisconsin: Geology of Wisconsin, vol. 2, p. 577, 1877.

[3] Alden, W. C., Quaternary geology of southeastern Wisconsin: U. S. Geol. Survey, Prof. Paper 106, pp. 207–208, 1918.

Bluff" by some of the present inhabitants of the neighborhood, it seems preferable to commemorate the old settler who first exploited its resources. His old workings, around which the ruins of the kilns are still visible, have recently been reopened for agricultural limestone.

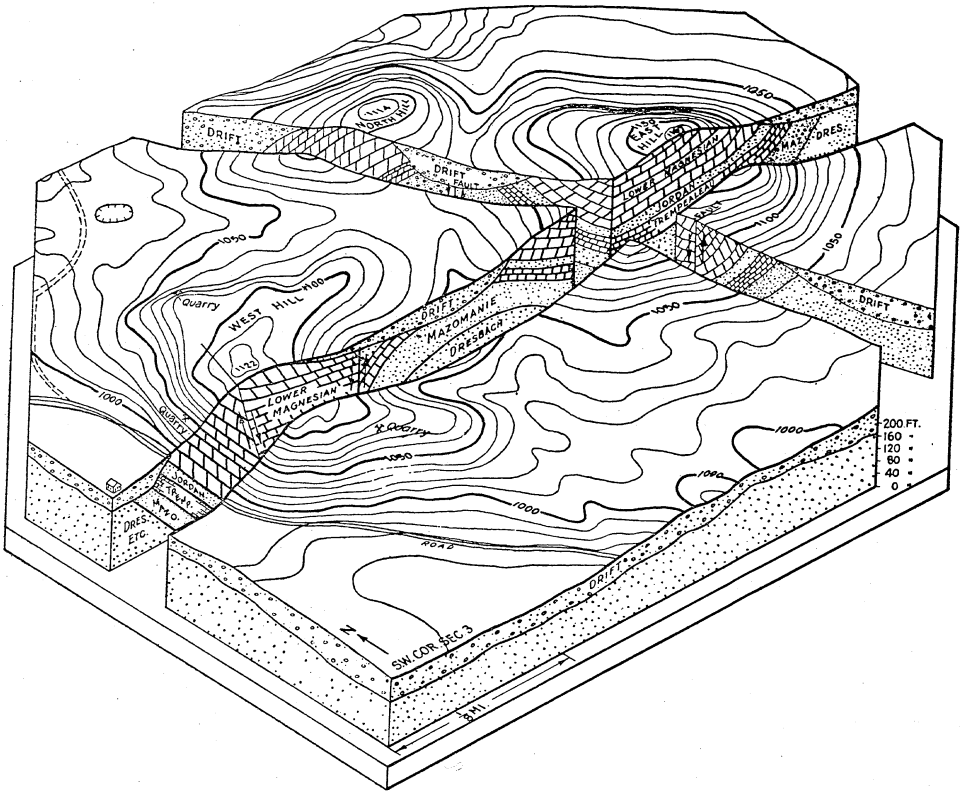

FIG. 1. Isometric block diagram of Glover Bluff, Marquette County, Wisconsin. Based on topographic map by G. L. Ekern, 1928. Sections redrawn by F. T. Thwaites, 1929. Contour interval 10 feet. Surface distribution of formations is not shown. The east–west section shows three of the fault blocks of West Hill. North Hill is a continuation of the middle block of West Hill, but its structure is obscure. East Hill consists of a faulted syncline which pitches to the west. The east–west fault possibly cuts through the south part of West Hill.

Topography. In order to permit the mapping of the geologic structure the bluff was surveyed topographically by the senior author whose map is here reproduced as an isometric block

diagram (fig. 1). Sea level elevations were obtained from the profile of the Soo Line which runs about two miles east of the area and thence carried to the southwest corner of Section 3 by aneroid. From there hand levels were run. Locations were obtained by pacing and plane table on the assumption that the subdivisions of the section are the exact dimensions they were intended to be. The diagram shows that the Bluff has three distinct summits, here designated as North, West, and East Hills. Of these, the highest is East Hill, 1167 feet.

Geologic Column of Vicinity of Glover Bluff

Period	*Formation*	*Character*	*Approximate thickness, Feet*
		Exposed rock formations	
Ordovician	Lower Magnesian (Shakopee and Oneota)	Dolomite, gray, cherty	200
Cambrian	Jordan	Sandstone, white and yellow, medium to fine grained, top quartzitic	20
Cambrian	Trempealeau	Dolomite. sandy, yellowish gray, thin bedded	30
Cambrian	Mazomanie	Sandstone, fine grained, red, yellow, white, dolomitic, glauconitic	75
Cambrian	Franconia	Sandstone, fine to very fine grained, green, red, gray, very glauconitic; gray, sandy, micaceous shale at base	25
Cambrian	Dresbach	Sandstone, medium grained, white, thick bedded, ripple marked, round-headed trilobites at top	100
		Concealed rock formations	
Cambrian	Eau Claire	Sandstone, fine to medium grained, gray, thin bedded	200
Cambrian	Mt. Simon	Sandstone, coarse grained, light gray, heavily bedded, some shale beds	300
Pre-Cambrian	----------	Igneous and metamorphic rocks	---

General geology. Glover Bluff is situated in the glaciated portion of the Cambrian sandstone area of central Wisconsin and was entirely covered by the ice sheet. The terminal moraine of the Middle Wisconsin drift is about three miles west of the Bluff. The immediate vicinity of the Bluff is a pitted outwash plain composed almost wholly of sand. Through this plain project small areas of excessively sandy recessional moraine. The bed rock formations of the vicinity are of Cambrian and Ordovician age as shown in the following columnar section. The three youngest formations are present only on Glover and Bald Bluffs. These two dolomite outliers are over 40 miles from the main area of Lower Magnesian dolomite.

General structure. The Paleozoic rocks around Glover Bluff dip gently to the south of east. Aneroid readings corrected by frequent checks on known points indicate that the base of the Lower Magnesian on Bald Bluff (Sec. 7, T. 17, R. 8 E.) lies at about 1180 feet. As this contact is not preserved east of Glover Bluff, recourse was had to the base of the Franconia shale. This horizon is now exposed in many pits since it is used for road surfacing. The base of the shale is at 1020 feet elevation near the sandstone quarry in SW¼ Sec. 1, T. 17, R. 8 E., at 1060 feet in SW¼ Sec. 1, T. 17, R. 7 E. six miles to the west, and at 1090 feet in Pilot Knob (NE¼, Sec. 3, T. 17, R. 7 E.). No attempt was made to trace the structure of the surrounding region in detail, but it is clear that neither folding nor faulting is present outside of the immediate neighborhood of Glover Bluff.

Structure of Glover Bluff. If the dip is uniform from Bald Bluff east, we should expect to find the base of the Franconia shale at elevation 1040 at Glover Bluff and the base of the Lower Magnesian at elevation about 1160. Instead we find sandstone, which is either Franconia or Mazomanie, immediately southwest of East Hill at elevation 1030. The top of the Jordan sandstone is found on the south slope of East Hill at about 1075 and in a highly disturbed state on the southeast side of West Hill at about 1065. On West Hill Lower Magnesian dolomite occurs down to less than 1010 feet and dips steeply down to still lower levels (fig. 1, section). It is obvious, therefore, that Glover Bluff is a down-folded or down-faulted element which extends at least 200 feet below the expected level of the formations.

FIG. 2. Steeply inclined Lower Magnesian dolomite in quarry at west end of West Hill, Glover Bluff, looking north. Photograph by W. O. Hotchkiss, 1919.

FIG. 3. Lower Magnesian dolomite on southeast slope of East Hill, Glover Bluff, dipping into hill forming synclinal basin. Looking west. Photograph by F. T. Thwaites, 1928.

West Hill. Quarry workings on the west end of West Hill exposed in 1928 the following section measured by the senior author and shown in part in figure 2.

	Feet
11. Dolomite, layers 6 inches to 2 feet, light gray, fairly hard, some white chert nodules, conglomerate of chert and dolomite pebbles at bottom	25
10. Dolomite, layers 3 inches to 1 foot, light gray, hard	21
9. Dolomite, layers 1 foot to 8 feet, yellowish gray, fairly hard, some white chert nodules	75
8. Dolomite, gray, sandy, soft	½
7. Dolomite, 2 foot layers, gray	4
6. Dolomite, layers 3 inches to 1 foot, gray	2
5. Dolomite, layers 1 foot to 4 feet, gray, sandy	11
4. Dolomite, gray, sandy, soft	½
3. Dolomite, layers 1 foot to 3 feet, gray	10
2. Dolomite, layers 6 inches to 1 foot, gray	3½
1. Dolomite, layers 1 foot to 2 feet, gray, fairly soft, very sandy, gray	30
Total	182½

The conglomeratic layer, which was noted by Hotchkiss, may mark the base of the Shakopee formation. No fossils except some Cryptozoon domes were discovered. The strike of these beds is about north 20 degrees east and the dip varies from 65 to 80 degrees to the east. In the excavations on the west side of the hill there is no evidence either of minor faulting or brecciation, but the layers are firm and very difficult to quarry. On the south side of the hill, however, minor faulting and variation in dip and strike are observed. In an old quarry in the middle of the south side of West Hill the strike is about north and the dip is 35 degrees to the east. A few rods south from that point the strike is east and the dip 10 degrees to the north. These two exposures are probably separated by an east-west fault. Lower down the hill to the west the beds also dip to the north and are hence classified as part of the same fault block. On the southeastern point of this hill dolomite float ceases along a sharp line and small outcrops east of that line show white quartzitic sandstone which locally contains quartz pebbles; some of this sandstone is red and dolomitic. It is possible that this end of the hill is a fault block which is separated from both of the other blocks by a fault which trends northeast between North and East Hills. (Fig. 1.) On the north end of

East Hill is an abandoned quarry in much fractured cherty dolomite. The beds at this point appear to be horizontal. Directly south of this quarry, between the active workings on the west side of the hill and the old quarry where the dip is 35 degrees to the east is an exposure in which the strike is northeast. Here a definite line divides vertical beds on the northwest from horizontal layers on the southeast. This fact makes it hard to interpret the horizontal beds as due to a flattening of the dip toward the east. The interpretation arrived at is that there are at least four fault blocks in West Hill: (a) the western block with layers dipping steeply to the east, (b) a central block with mainly horizontal beds, (c) an eastern block probably with highly inclined strata, and (d) a southern block of comparatively horizontal beds. The fault between blocks (a) and (b) is thought to strike about north 10 degrees east. The mechanics of such faulting are obscure and the possibility must be recognized that some of the dips may be erroneous on account of slump of large masses of rock. Viewed broadly, the structure is a syncline the center of which has dropped dragging down adjacent beds. Little could be told of the amount of displacement as the character of the strata precludes accurate identification of different beds.

East Hill. Although there are no quarries on East Hill, natural ledges are abundant and enable a good idea of the structure to be obtained. This is a synclinal basin which, on the south side, is broken by a fault with an east-west strike and vertical dip. Along this fault, which is very well exposed for 15 to 20 feet of its course, beds on the north side have a strike north 25 degrees east and a dip of 10 degrees west. These layers abut on strata with east-west strike and a dip of 45 to 100 degrees to the north. It seems likely that this fault is a continuation of the southern or east-west fault postulated in West Hill. If so, it must either die out to the east or turn north, for good ledges (fig. 3) fail to show it on the eastern end of East Hill. Instead the strike of the beds changes gradually as one follows the strata to the nose of the hill so that there it is north and the dip is west. Thus a westward plunge of the syncline is clearly demonstrated. The displacement on the fault is hard to estimate. On the basis of supposed equivalence of beds on the two sides, the senior author estimated that the movement was only 8 feet, but this seems impossible in

view of the abrupt change of dip and the thickness of beds involved in the tilted zone south of the fault. Similarity of conditions to those on West Hill strongly suggest that the structure is the same and that the downthrow of the fault is on the north side thus dragging down the formations on the south. The fault may be of the hinge type with the displacement increasing toward the west. The fact is that the dip of the southern fault block is progressively less as one goes east from the point where the fault is exposed. Exposures are poor on the north and northwest sides of East Hill. Strong indications of a dip into the hill were observed at two points. It seems improbable that these small exposures can be blocks which have either slid down hill or have been moved by the glacier for the thin beds are too little fractured to admit of much displacement except under heavy load. The synclinal structure evidently extends south of the outcrops (fig. 1), for the vertical interval between the exposure of the base of the Lower Magnesian and the pit in sandstone is too small for the normal thickness of the formations. Strata in the sandstone pit appear to be horizontal, but weathering prevented accurate observations. It is possible that other faults exist than those shown.

North Hill. North Hill had apparently never been visited by a geologist until the work of the senior author. It is entirely covered with dolomite float, but the only exposure of strata is a prospect pit on the northwest side. By doing a little excavating the formation was found to be dolomite in two to four inch beds. The strike appears to be northeast and the dip 33 degrees to the northwest. Ripple marks demonstrate that the strata have not been overturned. The difference between the structure of this hill and that of the others casts doubt on the reliability of this observation. It is possible that weathering has caused the beds to slump until the apparent dip is opposite to the true dip. If the observed dip is really correct, North Hill is the northern limb of an anticline whose crest lies in the valley between the three hills. This interpretation is given in figure 1. A southerly dip demands a fault between the two bluffs which would be an extension of the fault indicated near the southeastern end of West Hill. A northerly dip demands a fault or fold north of the hill. Unless considerable rock excavation is done on North Hill, its structure will remain obscure. The senior author concluded that the thin bedded strata

on North Hill are the same as those found on the other two hills, but ripple marks were found only at this locality.

Origin of the structure. The only previous explanation of the structure of Glover Bluff is that of Alden[4] who concluded that glacial shove removed a body of horizontal dolomite strata from the crest of West Hill and dumped it in a confused mass at the bottom of the west slope. It is evident that Alden did not realize the presence of faulting and folding in the other hills. Any explanation of the structure must recognize both the extent and complexity of the deformation and the fact that all the formations are far below their normal position. The glacial hypothesis seems to the writers to be totally inadequate to explain these facts; moreover, so great a thickness of dolomite would not have been present on such a small bluff so far from the main body of the formation and it could not have been moved very far without more breaking and mixture with drift than is present. Deformation of the strata must have taken place before erosion to anything like present conditions, for the layers were moved without excessive fracturing. Two other theories remain to be considered: (a) concealed vulcanisim in post-Ordovician time, and (b) renewed movement on a pre-Cambrian structure.

Volcanic hypothesis. Local disturbed areas surrounded by almost horizontal strata have been described in southern Ohio, Kentucky, and northern Tennessee. Bucher and Jillson[5] both regard these as due to concealed volcanic activity. An area of very local uplift in northwestern Indiana has been described.[6] Glover Bluff differs from all of these structures in being depressed rather than uplifted. It seems to the writers that if either igneous intrusions or gas explosions had taken place

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[4] Alden, W. C., Op. cit.

[5] Bucher, W. H., Cryptovolcanic structure in Ohio of the type of the Steinheim basin (abstract): Geol. Soc. America, Bull., vol. 32, pp. 74–75, 1921; Jillson, W. R., An isothrustic hypothesis: Kentucky Geol. Survey, Ser. 6. vol. 30, pp. 61–69, 1927; Pan-Am. Geologist, vol. 40, pp. 251–258, 1923.

[6] Ward, L. C., Road materials of Newton County: Indiana, Dept. Geol. and Nat. Res., Thirtieth Ann. Rept., pp. 214–217, 1906; Cumings, E. R., Nomenclature and description of the geological formations of Indiana: Indiana, Dept. Conservation, Geol. Survey, Handbook of Indiana geology, p. 449, 1922; Chamberlin, R. T., On the crustal shortening of the Colorado Rockies: Am. Jour. Sci., 5th ser., vol. 6, p. 217, 1923; Cumings, E. R., and Shrock, R. R., The geology of the Silurian rocks of northern Indiana: Indiana, Dept. Conservation, Geol. Survey, Pub. 75, p. 137, 1928; Shrock, R. R., and Malott, C. A., Notes on some northwestern Indiana rock exposures: Indiana Acad. Sci., Proc., vol. 39, in press.

three results would be inevitable: (a) excessive brecciation of the rocks, (b) formation of dikes and mineral veins containing substances and compounds known to be deposited by hot solutions, and (c) uplift of formations above their normal position. None of these features is present at Glover Bluff and thus the volcanic hypothesis is definitely eliminated.

Fault hypothesis. Faults in the Paleozoics of Wisconsin have been observed at several points throughout the state and at some of these the actual plane of movement is exposed. Ulrich[7] described a fault only a few miles west of Glover Bluff, just south of Pilot Knob. Careful investigation by the writers using the Franconia shale as a key bed demonstrated that such a fault does not exist at the locality indicated. Existing information does not suggest that the Glover Bluff structure is related to any known system of extensive faults or folds in the Paleozoics. Nevertheless, it seems reasonable to suggest that a small graben or syncline in the concealed pre-Cambrian beneath Glover Bluff may have suffered renewed movement in post-Ordovician and pre-Pleistocene time. If such a concealed structure is present, it might easily make its presence known by variations from normal magnetic attraction. The senior writer ran a line across Glover Bluff with an ordinary dip needle without results. An extensive survey with the Hotchkiss super-dip needle might yield better results, but time and funds have been lacking for such work from which economic results could not be expected.

Conclusion. Pending extensive geophysical work the origin of the Glover Bluff structure must remain unsettled although the probability favors the hypothesis of deformation due to later movements on pre-Cambrian lines of weakness.

Madison, Wis., Dec. 15, 1929.

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[7] Ulrich, E. O., Major causes of land and sea oscillations: Washington Acad. Sci., Jour., vol. 10, p. 75, 1920.

THE VARVED CLAY DEPOSIT AT WAUPACA, WISCONSIN

E. W. ELLSWORTH AND W. L. WILGUS

Abstract. The article presents the results of studies of the varved clay in an artificial opening near Waupaca, Wisconsin. The occurrence is described in detail and the mineral components of the clays listed.

Introduction. Varved clays have been recorded in Wisconsin at five localities: Menomonie (Dunn County), Grantsburg[1] (Burnett County), Manitowoc (Manitowoc County) and New London and Waupaca (Waupaca County). In 1920 the clays at Manitowoc, New London, and Menomonie were measured and correlated by Ernst Antevs.[2] The varved clay at Waupaca has since been exposed (see fig. 1), and furnishes the basis for the studies given in this paper. The work was done in the Sedimentation Laboratory of the University of Wisconsin and the writers' thanks are due to E. F. Bean, State Geologist, W. H. Twenhofel and F. T. Thwaites, for helpful suggestions, advice and criticism.

Location. The Waupaca varved clay deposit is shown in a single exposure in the brick yard of Conrad Gmeiner and Sons, located in the northeast quarter of the northwest quarter of Section 33, Town 22 north, Range 12 east, of the 4th principal meridian, Waupaca County, Wisconsin. It is situated on the flood plain of the Waupaca River, about 1½ miles east of the city of that name.

General geology. The clay seems to be confined to the immediate vicinity of the pit and has been reached in only a single neighboring well. It thus appears to be a pocket, perhaps in a preglacial valley, or a kettle-hole, which has here been exposed by the postglacial erosion of the Waupaca River. The sides of

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[1] Berkey, C. P. Laminated interglacial clays of Grantsburg, Wisconsin, with chronological deductions. Jour. Geology, Vol. 13, pp. 35–44. 1905.

[2] De Geer, Gerard. On the Solar Curve, as dating the Ice Age, the New York moraine, and Niagara Falls through the Swedish time scale. Geografiska Annaler, Vol. 8, pp. 253–283. 1926. Note: The locality at Menomonie, Dunn County, Wis. was erroneously given as Menominee, Michigan.

the valley show that before erosion the clay was overlain by the Red Drift,[3] of the late Wisconsin Stage of Glaciation. This fact correlates the clay with the latter part of the Middle Wisconsin Stage and makes it a deposit in Early Glacial Lake Oshkosh.[4] Two drill holes at the clay pit show that the clay continues to a depth of 176 feet, and rests upon solid rock, probably pre-Cambrian granite. The geologic section exposed at the clay pit is as follows:

	Feet
4. Till, red, pebbly, formerly worked for brick clay	3
3. Sand, silty, reddish brown to gray, without pebbles	40
2. Clay, varved, summer components gray, winter, red	176
1. Bed rock?	---

The exposed clays consist of alternate laminations of blue-gray and chocolate-brown clay; the red beds being darker and appearing as black lines in the photograph (fig. 1). The light gray laminations, which are thicker and more silty than the red, grade into the overlying red, but are sharply separated from the underlying red laminations. A gray layer and the succeeding red layer comprise an individual varve, whose average thickness is about three centimeters. The exposed section is twelve feet thick and contains the ninety-nine varves which were studied in detail, and a one to two foot zone of highly folded and contorted varves occurring immediately beneath the undisturbed varves shown in fig. 1. A section of this zone of deformation is shown in fig. 2.

Detailed studies of the varved section. By means of three four-foot metal troughs, the complete twelve-foot section seen in fig. 1 was taken to the Sedimentation Laboratory of the University of Wisconsin. After careful measurement of the varve components the graph given in fig. 3 was constructed. As the curve of total varve thicknesses is used in Baron De-

[3] Alden, W. C. Quaternary Geology of southeastern Wisconsin; U. S. Geol. Survey, Prof. Paper 106, pp. 310–324. 1918.

[4] The name, Glacial Lake Oshkosh, applies to the glacial lake of the Fox and Wolf valleys, which overflowed through the low divide between the Fox and Wisconsin Rivers near Portage, Wisconsin. The name Early Glacial Lake Oshkosh is applied to the higher and earlier (Middle Wisconsin) level of glacial waters in the same basin. Upon the suggestion of Alden that the former name Glacial Lake Jean Nicolet of Upham, be discarded because of confusion with another glacial lake of similar name, the name Glacial Lake Oshkosh was given by Thwaites in 1927, on the basis of unpublished geological work on Waupaca and adjacent counties. Later Glacial Lake Oshkosh is the name applied to the lower and later (Late Wisconsin) level of glacial waters in the same basin.

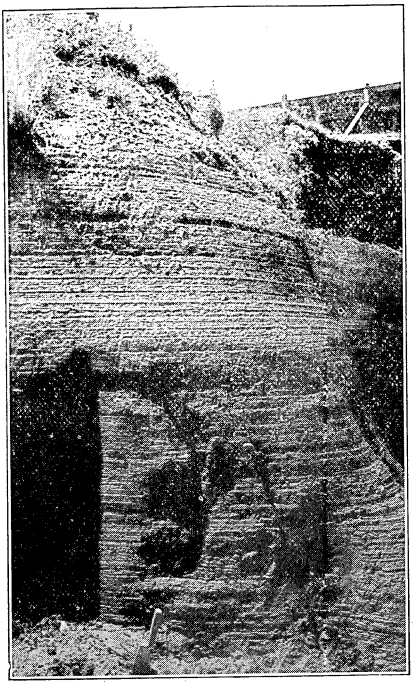

FIG. 1. Section of the Waupaca varved clays. Photograph by F. T. Thwaites.

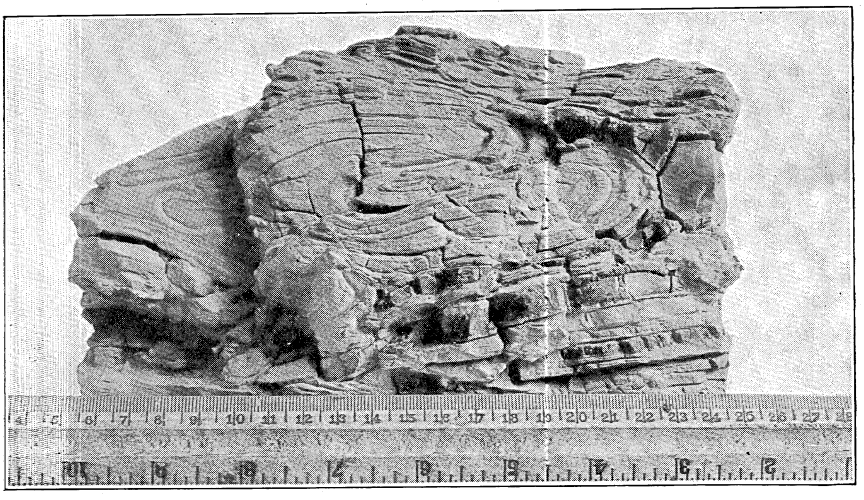

FIG. 2. This photograph illustrates the type of deformation common to a one to two foot zone which occurs directly below the twelve-foot section of practically undisturbed varves. (See figure 1). Two overturned, recumbent folds are shown and irregular foldings produced in the silty layers, as seen on the smooth face to the left. The darker layers have yielded less, though they were thinned out in the process of folding. The deformation in this zone is referred to the grounding of icebergs. Photograph by F. T. Thwaites.

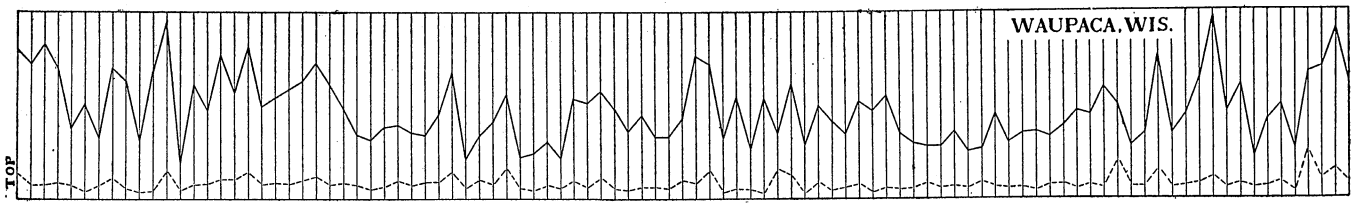

FIG. 3. Diagram to illustrate the composition of the curve of total varve thicknesses which is used in making correlations of varved clay deposits. Each vertical line corresponds to one varve, the oldest being at the left, or "Top". Upon each line is set off the actual thickness of that whole varve, the distances being measured from the bottom line of the graph. These points are joined by a full line. The lower and broken line joins those points which represent the thickness of the winter components, and which are set off from the same base line. The thickness of the summer component of any varve is the distance between the two curves on the vertical line corresponding to that varve. Full size of drawing was 19 inches.

Geer's method of correlation, it was thought advisable to study the components of this curve, which are here shown graphically.

From a study of this graph the following conclusions were reached:

(1) Thick winter components generally occur in thick varves, but thick varves do not necessarily indicate thick winter components.

(2) Thin winter components are associated with thin varves and thin varves comprise winter components of a thickness below average.

(3) The varves are remarkably uniform in thickness, their total thicknesses range from 1.33 to 6.90 centimeters, with an average of 3.27 centimeters.

Measurements of the size of the constituent mineral grains gave results as follows:

(1) There is no direct relation between the thickness of a varve and the coarseness of its constituent grains.

(2) A high degree of assortment is attained in the varve components. Just as the summer components are composed almost entirely of particles falling well within the range of silt (1/16–1/256 mm.), so the winter components comprise grains all of which come under the classification of clay (smaller than 1/256 mm.).

Contemporaneous deformation is obvious in the Waupaca clays. Folding, faulting and brecciation of a microscopic order of magnitude are common and appear to be the result of deformation due to settling and sliding of the clay beds. Marked deformation of a larger order of magnitude is confined to a more or less well defined horizon (fig. 2) and is believed to be the result of the grounding of icebergs.

The only evidence of organic remains in the clay are a solitary spruce needle found in the bottommost varve of the section, and a very small and delicate plant-fibre taken from one of the summer components. The plant-fibre appears to be part of a land plant that had been blown into the lake during the summer, or swept out upon the ice cover during the fall and winter.

The following facts suggest that the banding is seasonal:

(1) The entire exposed face of the deposit is made up of alternating layers of red and gray clay.

(2) Each gray layer grades into the overlying red, whereas the boundary between the red and gray above is a sharp line

in ninety-eight cases out of the ninety-nine red layers included in the section studied.

(3) Though the average thickness of the gray layers is approximately six times that of the red, there is a remarkable uniformity in the thickness of these layers as shown in fig. 1.

(4) None of the red layers is streaked with fine layers of gray, whereas the bottom parts of several of the gray layers contain streaks of red clay.

(5) The red layers reveal no traces of bedding, but appear to be altogether homogeneous. Fine bedding lines are characteristic of the gray and close examination reveals many alterations of coarse and fine sediments, as many as forty being counted in a single gray layer of average thickness.

(6) The red layers are composed almost entirely of particles falling within the classification of clay and the gray particles come almost wholly in the range of silt.

(7) Thirty-nine of ninety-nine of the gray layers contain one or more thin beds of a very fine sand.

(8) Ripple marking occurs only in the gray layers. In appearance the red layers resemble flat, thin slabs of hard chocolate.

(9) There is a lack of microscopic organic matter in both the gray and red layers, with the exception of the solitary spruce needle and plant-fibres noted above.

It is apparent that a gray layer and the succeeding red layer represent a definite unit. The boundaries of this unit, which is known as a *varve,* are sharp and well defined; whereas the components grade into each other. The varve layers not only possess a unity of their own, but (1) they indicate an apparent repetition of the same series of conditions controlling their formations, and (2) they necessitate the condition of a periodic supply, interrupted by times when the waters of deposition were practically free of agitation so as to allow the settling of the finest clay. That the clays are of glacial origin may be concluded from (1) their lack of organic matter, (2) their content of rock flour, especially pulverized limestone and (3) their field relationships. The above summary suggests that annual changes, due to the cyclic repetition of the summers and winters, were responsible for the deposition. The required condition of periodic supply separated by intervals of non-supply noted above is satisfied by the influx of sediment during

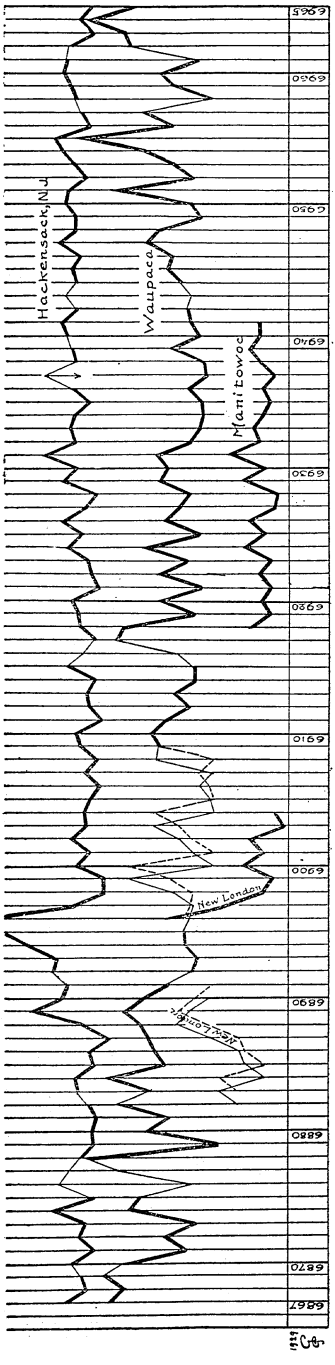

FIG. 4. De Geer's correlation of the Waupaca varved clay. The numbers denote years before the final year of the Ice Age, as recorded by De Geer. Full size of drawing was 20 inches.

the summer months, which were followed by periods of complete cessation of supply,—when the glacial lake was ice-bound, and allowed the settling of the finest particles brought in during the previous summer.

From the present study of the Waupaca clays the evidence seems to be such as to confirm the opinion that the melting of the bottom ice during the winter, due to the radiation of the interior heat of the earth, is either altogether lacking, or is a negligible factor.

Correlation of the Waupaca varved clays. A varve curve of the section was made after the method described by Antevs,[5] and was sent to Baron Gerhard DeGeer. DeGeer states[6] in a letter: "The varves at Waupaca seem to be normally developed and fitted very well to the curve from the named localities (Hackensack, N. J., New London, Wisconsin and Manitowoc, Wisconsin); with respect to several characteristic variations so well that the connection seems to be certain. Thus the lowermost varve of your Waupaca section corresponds to the year 6965 and the uppermost one to the year 6867 before the final year of the Ice Age." DeGeer's correlation is presented in figure 4.

The validity of the correlation of the Waupaca deposit with the varves of both New London and Manitowoc, Wisconsin, is not supported by the field relations of these deposits. The section at the Waupaca deposit clearly shows the varved clays to be older than the Red Drift of the Late Wisconsin stage of glaciation. At both Waupaca and Manitowoc the Red Drift of Late Wisconsin age overlies the varved clays. A careful search failed to show any such layer above the New London clays, which thus appear to be distinctly younger in age, and to be products of Later (Late Wisconsin) Glacial Lake Oshkosh. This would show that either the New London, or the Manitowoc clay has been erroneously correlated with the solar curve of DeGeer, and hence the age assigned to one of them invalid. In either case the Waupaca clay cannot be made to correlate with that of New London. While in figure 4 the matching of the curve from Manitowoc with that from Waupaca might be taken as a reasonable correlation, the shifting of the curves to bring

[5] Antevs, Ernst. Retreat of the last ice sheet in eastern Canada; Geol. Survey, Canada. Memior 146, pp. 9–12, 1925.

[6] Letter of March 7, 1929.

about the New London correlation seems to indicate that this is the source of error,—the New London curve not belonging there at all. Moreover, the chemical and physical properties of the New London clays are quite unlike those at Waupaca. With the two deposits separated by a distance of less than eighteen miles, and both lying in the drainage basin of the Wolf River, it would seem reasonable to expect their chemical and physical properties to be quite similar if they are of the same age and were deposited in the same body of water.

Chemical and physical properties of the Waupaca varved clays. A chemical analysis of the Waupaca clays showed the following:

(1) The iron content of the red clay components (5.49% Fe_2O_3) is higher than that of the summer components (2.34% Fe_2O_3).

(2) The percentage of carbonates (31.65% $CaCO_3$, $CaMgCO_3$) in the winter components is 1.5 times that in those of the summer (22.05%).

(3) These differences in chemical composition of the varve components appear to reflect the fine state of division of the ferric iron and calcite and dolomite particles carried into the glacial lake.

The physical properties of the varve components are quite unlike. The red winter laminations possess a greater plasticity than do the gray silt ones. Upon drying the red clays become hard and brittle, whereas the gray silts lack cohesive forces sufficient to resist crumbling between the fingers. When both summer and winter components are mixed together, as in the soft mud process of brick manufacture used at Waupaca, the resulting clay, when thoroughly dried, is remarkably hard and firm, and may be handled just as finished brick. The reason for this is not altogether clear; but it would seem that in some way it is related both to differences in physical texture and to chemical composition of the varve layers. In a natural mixture of both layers there are six times as much gray silt as red clay, the texture of the latter would seemingly allow for its constituent grains to fill all the interstices of the coarser silt and thus act as a binder. Considering this phenomenon from the chemical side, it will be recalled that the carbonate content of the two components is quite different, that of the red being 1.5 times that of the gray. This raises the question as to

whether or not the different components are characterized by carbonate and other solutions of varying concentration, and whether or not the intermingling of such solutions in the mixing of both layers brought about any precipitation, as of calcium carbonate, for instance, which might act as a natural cement. The varved clay is saturated with water at the pres-

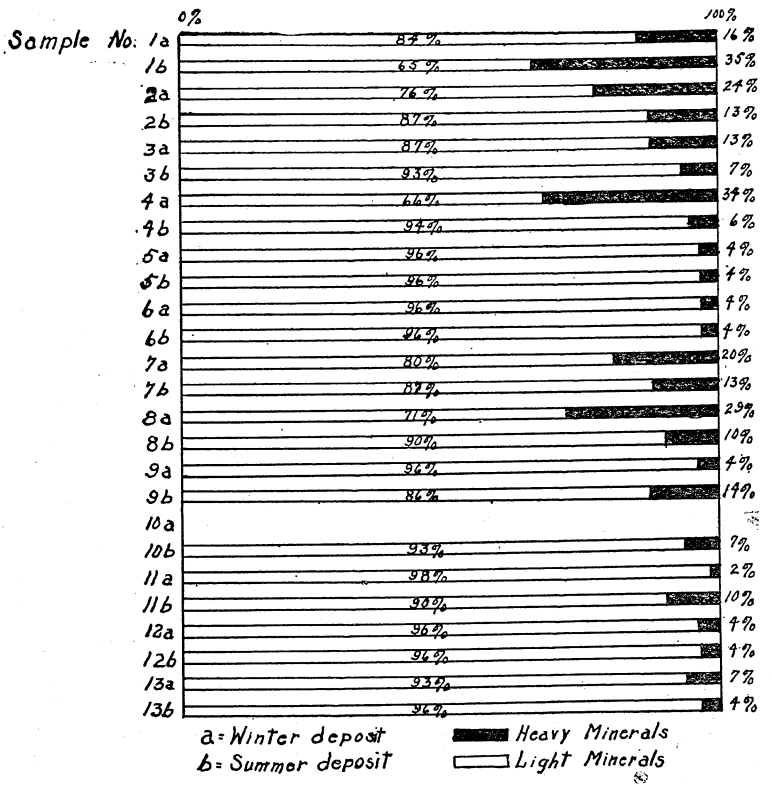

FIG. 5. Diagram showing percentage by weight of heavy and light minerals present in each sample.

ent, and the indications are that it has been this way ever since deposition. Knowing the red layers to be highly impervious, it seems reasonable to assume that in the unfolded layers, whatever movement of the groundwater has taken place, has been mostly along the lamination planes and not from one lamination to the next. The condition would be favorable to the development of solutions characteristic of each lamination and

seemingly explain why, in the natural state, there would be little intermingling of such solution, and hence no precipitation.

Petrography of Waupaca clay. For the purpose of making a petrographic study of the varved clays, twenty-six samples, ranging from two to fourteen grams each, were taken at inter-

	Heavy Minerals																	Light Minerals				
	Epidote	Hornblende	Zoisite	Cyanite	Topaz	Zircon	Garnet	Rutile	Hypersthene	Enstatite	Staurolite	Andalusite	Sillimanite	Apatite	Chlorite	Unknown	Opaque	Quartz	Calcite	Feldspar	Chlorite Coated with Iron oxide	
Sample No. 1a	x	x		x	x										x		8	x		x		99
1b	36	42			x						4(?)						18	82	12	6		
2a	28	28	2		4		x					x?	4?	4			30	x	x	x		90
2b	40	25	1				4					2				x	28	80	10	6	4	
3a	x	x		x					x			x					x	x	x	x	x	90
3b	38	30				2	4		2		x?						24	76	13	10	1	
4a	32	26		2		2	4		x								34	x	x	x		75
4b	34	24				4	4						2?				32	65	21	8	6	
5a	22	22	2		x	2	x										52	56	34	10	x	
5b	42	24			2												32	64	30	4	2	
6a	32	20			2		x			x?			2?				44	x	x			98
6b	40	46		2	2	x	x										10	57	37	4	2	
7a	40	18			4	2				x?					x		36	x	x	x		98
7b	32	26	2		2			2	x								36	66	28	4	2	
8a	34	28		2													36	x	x			97
8b	44	34	2	2	2		x		x								16	64	24	8	4	
9a	30	24	2				x				x						44	x				99
9b	36	18	4		4												38	52	42	6	x	
10a	28	14	2	2	2		x				x						50	x	x	x	x	85
10b	34	26	2		2	2	x										34	62	32	2	4	
11a	32	24	6		2	x				x?						2	34	x	x		x	96
11b	42	30	2		2		2										22	50	42	4	4	
12a	32	26	2	2	x	2											36	60	34	4	2	
12b	38	28	2			x	2								2	x	28	62	24	4	10	
13a	32	24	2			x											42	x	x		x	98
13b	38	24	4	x		2	x								4	2	26	60	26	4	10	

FIG. 6. Chart showing the percentage of each mineral present in each sample; a represents winter deposit, b summer deposit; x equals trace—found, but not in grains counted.

vals from the twelve foot section. When a sample was taken from a winter component, another sample was taken from the following summer component.

To separate the clay from the minerals, the process of decantation was used. It was found that approximately fifteen to eighteen decantations were necessary for the summer component, whereas twenty-one to twenty-five decantations were

necessary for the winter component. This difference is due to the presence of a large quantity of iron oxide, which, together with the clay, forms a coating on the mineral grains of the winter components, though it does not occur on the summer components. This coating could not be entirely removed. It does not seem to be present on the heavy minerals to such an extent as on the light. In some samples this coating is so great that the minerals could not be determined.

Separations of light and heavy minerals were made with tetrabromoethene (G 2.9). The weight of both the light and heavy minerals was recorded and the percentage of each determined. A chart (fig. 5) showing these results was made for the purpose of comparing the relative quantity of heavy minerals in summer and winter components. A study of this chart shows that the summer components generally contain more heavy minerals than do those of winter.

The results of the petrographic study of each sample are recorded in fig. 6. The opaque minerals, epidote, and hornblende, are the most abundant heavy minerals; other heavy minerals are comparatively rare. The opaque minerals are most abundant in winter components; epidote is the most abundant in the summer components. No explanation is given for these differences.

Quartz and calcite are the commonest of the light minerals, with feldspar and chlorite occurring in small quantities. As several of the light minerals of the winter components are coated with iron oxide, no accurate comparison of the light minerals of the summer and winter components can be made. A chemical analysis of the coated light mineral grains of the winter component shows that 35 per cent by weight of these grains are carbonates and that the remaining 65 per cent of the grains are made up of quartz, feldspar, and chlorite.

Measurements of the grains for both summer and winter components gave the following:

	Heavy Minerals		*Light Minerals*	
	Winter	*Summer*	*Winter*	*Summer*
Size of smallest grain identified	0.05mm.	0.05mm.	0.05mm.	0.05mm.
Size of largest grain identified	0.15mm.	0.21mm.	0.25mm.	0.30mm.
Size of average grain identified	0.07mm.	0.09mm.	0.09mm.	0.13mm.

Summary

(1) Contemporary folding, faulting and brecciation of a microscopic order of magnitude are characteristic of the section and appear to be the result of deformation due to settling and sliding of the clay beds.

(2) Similar deformations on a larger scale are common to a more or less well defined horizon and are thought to indicate the action of grounding icebergs.

(3) The sharp upper boundaries of 99 per cent of the clay components suggest complete cessation of the supply of new sediment and the unity of each silt layer and the overlying layer of red clay is very apparent.

(4) None of the red clay components contain streaks of silt, or evidences of any irregularity in their deposition.

(5) Ripple marks and laminations due to water currents are common in the gray silt components, but are not present in the red clay components.

(6) The entire section indicates a cyclic repetition of the same series of conditions which controlled the formation of these units and the orderly repetition of summer and winter seem to be their only reasonable explanation.

(7) The results of the present study directly oppose the theory of the melting of the bottom ice during the closed winter season, for during the winter, there was absolute cessation of the supply of sediment and wave action.

(8) The correlation of the deposit by DeGeer, makes it the product of deposition in Glacial Lake Oshkosh during the 70th century before the final year of the Ice Age, as recorded by DeGeer. But this correlation is also made with the New London clays, where no Red Till occurs, and with Manitowoc, where the overlying Red Till makes the clay of Middle Wisconsin age. By the cover of Red Till at Waupaca, the clay beneath is known to be of Middle Wisconsin Age. Thus the correlation of the Waupaca clay with that of New London appears to be in error.

(9) The iron content of the red clay components is higher than that of the summer components.

(10) The percentage of carbonates in the winter components is 1.5 times that in the summer components.

(11) These differences in the chemical composition of the varve components appear to reflect the fine state of division of

the ferric iron and calcite and dolomite particles which were carried into the glacial lake for deposition.

(12) The summer components generally contain more heavy minerals than do those of winter.

(13) The opaque minerals, epidote, and hornblende, are the most abundant heavy minerals; other heavy minerals are comparatively rare.

(14) The opaque minerals are most abundant in winter components; epidote is most abundant in the summer components.

THE COMPOSITION OF THE FAT OF THE SILVER BLACK FOX*

H. A. SCHUETTE AND RALPH W. THOMAS

(Contribution from the Laboratory of Foods and Sanitation, Department of Chemistry, University of Wisconsin)

The apparent lack of published information on the subject prompted an analysis of a specimen of the fat of the silver black fox which is a color variation of the ordinary wild red fox, *Vulpes fulva.* The results of this analysis, which is quantitative and in part qualitative, are herein recorded.

The material under examination was taken from animals bred in captivity on a typical Wisconsin fox ranch where they are reared on a cereal-horse flesh diet. This artificial environment, coupled with a change in the type of food which the animal in its wild state instinctively selects, has its effect upon the characteristics and composition of the fat which appeared to be of a coarse-grained consistency. That such differences in the fat of domesticated and wild animals of the same species are not unusual has been pointed out by Amthor and Zink.[1]

Chemical and physical characteristics. The more important chemical and physical characteristics of the rendered fat are

TABLE 1—*Chemical and Physical Characteristics*

Specific gravity 25°/25° C.	0.9122
Index of refraction 40° C.	1.4581
Melting point, °C.	32.6
Titer test, °C.	36.17
Iodine number (Wijs)	70.46
Saponification number	197.1
Soluble acids %	0.54
Insoluble acids %	93.72
Soluble volatile acids (Reichert–Meissl number)	0.44
Insoluble volatile acids (Polenske number)	0.34
Saturated fatty acids % (corrected)	32.92
Unsaturated fatty acids % (corrected)	55.99
Unsaponifiable matter %	0.41

* Acknowledgment is made to the Central States Silver Fox Farms, Lynxville, Wisconsin, who furnished the fat used in this investigation.

recorded in table 1. For the determination of these, except as otherwise noted, the methods[2] of the Association of Official Agricultural Chemists were followed. Separation of the saturated from the unsaturated acids was effected by the lead salt-ether method of Gusserow[3] and Varrentrapp[4] and appropriate correction made[5] for the small amount of unsaturated acids left with them when this procedure is used.

The more important of these constants are of the order of magnitude of those characteristic of fox fat.[1] The melting point is lower, a condition not unexpected in view of the artificial conditions under which the animal is reared and confined. The iodine number of this fat, which suggests non-drying properties, is higher than that of dog fat, a published value being 58.5.[1] For an animal fat it ranks rather high.

Unsaturated acids. Qualitative identification of the unsaturated acids was made by means of bromine addition[6] and permanganate oxidation[7] products. Bromination of an ether solution of the former under the conditions prescribed by Eibener and Muggenthaler[8] yielded a small amount of a bromide which, however, was not definitely identified as a derivative of linolenic acid. Evidence for the presence of two bromine derivatives was found in the filtrate. That fraction which was soluble in warm petroleum ether yielded linolic tetrabromide, whereas the presence of some oleic dibromide was indicated in the residual portion.

Oxidation of the potassium salts of the unsaturated acids with dilute potassium permanganate solution (1.5%) yielded a crystalline product which proved to be a mixture of dihydroxy- and tetrahydroxystearic acids. Separation of these acids was effected through the ether-solubility of the former and the solubility of the latter in boiling water. Evidence for the presence of hexahydroxystearic acid in the filtrate was not conclusive.

The foregoing brief statement of facts furnish, it is deemed, a reasonable basis for the assumption that the unsaturated acids of this fat consist, wholly or in part, of linolic and oleic acids, all of which have been identified in the order named by means of their bromine addition products and, in the reverse order, from their oxidation products.

Saturated acids. The saturated acids prepared by the lead salt-ether method[3,4] were esterified with methanol[9] and the mix-

ture of methyl esters fractioned under diminished pressure (table 2).

TABLE 2—*Analyses of Fractions Obtained by Distilling Methyl Esters of Saturated Acids*

Fraction	*Boiling point °C.*	*Pressure mm. Hg*	*Iodine number*	*Saponification number*	*Mean molecular weight*
1	140–150	5.0	9.18	224.2	250.1
2	150–155	5.0	11.10	215.0	260.9
3	155–165	4.5	18.30	213.3	263.0
4	165–170	6.0	24.32	198.7	282.3

The iodine number, as a measure of the degree of contamination by unsaturated acids, and the saponification value of each fraction were determined. From these data the mean molecular weight of each fraction was calculated.[9]

The calculated mean molecular weights of these fractions lie between C_{12} and C_{18} for esters of the type made. Their probable constituents are methyl myristate (242.2), methyl palmitate (270.3) and methyl stearate (298.4). Information subsequently obtained disclosed the fact that fraction 4 was a mixture of the palmitate and the stearate, whereas the remaining three consisted of varying proportions of the former and an ester of lower molecular weight. The latter was not identified, but it is quite probable that it is methyl myristate.

Summary. The qualitative composition of silver black fox fat may be expressed in terms of the glycerides of palmitic, stearic, oleic, and linolic acids. In its physical and chemical constants this fat bears some semblance to that of the wild fox, although the effects of confinement and artificial feeding are apparent.

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DETERMINATION OF ORGANIC PHOSPHORUS IN LAKE WATERS[1]

REX J. ROBINSON AND GEORGE KEMMERER[2]

Contribution from the Laboratory of Analytical Chemistry, University of Wisconsin, and Notes from the Biological Laboratory of the Wisconsin Geological and Natural History Survey. XXXV.

INTRODUCTION

In a study of the natural waters of Wisconsin, it is recognized that a direct application of the Denigès ceruleomolybdate reaction (1921) to the untreated water sample does not give the total phosphorus in the sample. However, if the sample is first given an oxidizing treatment, the application of the Denigès reaction then gives results which represent the "total" phosphorus. The values obtained by the direct application of the Denigès reaction to untreated water are referred to as "soluble" phosphorus while the values obtained from the water sample which receives the preliminary oxidizing treatment are considered "total" phosphorus. Deducting the "soluble" from the "total" phosphorus gives what may be called "organic" phosphorus. This "organic" phosphorus represents that which is contained in the plankton and other organic material that is present in the water, and a certain part of it may consist of dissolved phosphorus that is not in the penta-valent state.

Feeling that the determination of "total" as well as "soluble" phosphorus would add to our understanding of the phosphorus content of natural waters, Juday, Birge, Kemmerer, and Robinson (1927) presented a method for the estimation of total phosphorus. This method has been used in the field as well as in the regular laboratory since that time. Its use has suggested certain improvements and has given additional knowledge in regard to the limiting factors in the procedure. The research reported in this paper presents a modification of the

[1] Part of a thesis submitted by Rex J. Robinson in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

[2] On account of the death of Professor Kemmerer in November 1928, this manuscript was prepared under the general direction of Prof. V. W. Meloche.

original procedure for total phosphorus and gives the results of a critical examination of the main limiting factor, acidity.

Original Procedure

To the water sample are added 0.2 cc (four drops) of sulfuric acid and 0.5 cc of nitric acid which are then evaporated just to fumes of sulfuric acid. Ten to 20 cc of water are added together with 3 cc of concentrated hydrochloric acid and the evaporation repeated. When cool, the sample is diluted to 100 cc after which 2 cc of the molybdate reagent and 4 drops of stannous chloride are added. The blue color thus formed is compared with that from standard phosphate solutions treated in the same manner.

Solutions Required

Molybdate reagent. Ten grams of ammonium molybdate are dissolved in 100 cc of distilled water. This solution is added to 300 cc of 50% (by volume) sulfuric acid. It is necessary to protect from the light the solution so formed.

Stannous chloride. One gram of tin is dissolved in 20 cc of concentrated hydrochloric acid by gently warming and adding 2 drops of a 5% solution of copper sulfate. When the tin has dissolved, it is diluted to 100 cc and a piece of tin added to keep the stannous chloride reduced.

Standard phosphate solution. 4.394 grams of anhydrous potassium di-hydrogen phosphate (KH_2PO_4) are dissolved in water and diluted to one liter. One cc of this solution contains 1 mg of phosphorus. Solutions containing 0.01 and 0.001 mg of phosphorus per cc are made from this stock solution by appropriate dilution.

By this method of determination two evaporations are required, one when the organic material is destroyed by the nitric-sulfuric acid mixture and the other when the excess nitric acid is being destroyed by the hydrochloric acid. This procedure has been modified so that only one evaporation is required, thus saving considerable time.

Modified Procedure

The sample of water, to which has been added 0.2 cc of concentrated sulfuric acid, is evaporated to a volume of approximately 15 cc in a 250-cc Erlenmeyer flask. Then 0.5 cc of

concentrated nitric is added, followed by 3 cc of concentrated hydrochloric acid. The evaporation is continued just to the point where fumes of sulfuric acid are liberated. After cooling, the phosphorus is determined in the regular manner.

Checking Modified Procedure

Six 100 cc portions of a sample of Lake Mendota water were taken for the determination of total phosphorus, three by the former and three by the modified procedure. After the proper digestion, the phosphorus was determined by the Denigès ceruleomolybdate method. Some typical results are shown in Table 1.

TABLE 1—*This table shows the number of milligrams of phosphorus per liter of water*

Sample Number	*Former Procedure*	*Modified Procedure*
1	0.048	0.046
	0.046	0.046
	----	0.046
2	0.048	0.046
	0.046	0.048
	0.046	0.046
3	0.047	0.048
	0.047	0.048
	0.047	0.049
	----	0.048
	----	0.048

Discussion of Results

The results obtained by the two procedures were in close agreement. Since there is only one evaporation in the modified method, these results should be more accurate and possibly somewhat higher due to the fact that there is less danger of volatilizing a portion of the phosphoric acid. The results by the two procedures may be considered to be checks since the deviations are within the limits of experimental error for the determination.

Effect of Sulfuric Acid in Digestion Mixture upon the Colorimetric Comparison

Florentine (1921) stated that the acidity of the solution for the colorimetric determination of phosphorus must be care-

fully regulated to secure accurate results. Consequently the effect of the sulfuric acid in the digestion mixture previously described was determined. Various quantities of sulfuric acid were added to known amounts of phosphorus diluted to a 100-cc volume. These solutions were then treated with the regular reagents and the blue color so produced compared with standards which had been treated in the same manner, but without the additional amount of sulfuric acid. Table 2 shows this effect.

TABLE 2—*Effect of sulfuric acid upon intensity of blue color*

Drops of H_2SO_4 *Added*	*Milligrams of Phosphorus*	
	Taken	*Found*
1	0.0010	0.0009
2	0.0010	0.0010
3	0.0010	0.0009
4	0.0010	0.0010
5	0.0010	0.0010
1	0.0020	0.0019
2	0.0020	0.0019
3	0.0020	0.0020
4	0.0020	0.0020
5	0.0020	0.0019
1	0.0030	0.0030
2	0.0030	0.0029
3	0.0030	0.0028
4	0.0030	0.0027
5	0.0030	0.0027
1	0.0040	0.0039
2	0.0040	0.0040
3	0.0040	0.0038
4	0.0040	0.0035
5	0.0040	0.0034
1	0.0050	0.0050
2	0.0050	0.0050
3	0.0050	0.0049
4	0.0050	0.0046
5	0.0050	0.0043
1	0.0060	0.0060
2	0.0060	0.0060
3	0.0060	0.0057
4	0.0060	0.0052
5	0.0060	0.0050

Discussion of Results

The results in Table 2 show that the intensity of the blue color from small amounts of phosphorus, i. e. 0.0020 mg or less, is not appreciably affected even by five drops of sulfuric acid. With amounts of phosphorus larger than 0.0020 mg two drops of sulfuric have no effect although more than this amount of acid retards the development of the color considerably.

In the determination of total phosphorus in Wisconsin lake waters, there are two factors which tend to diminish the effect of the four drops of sulfuric acid in the digestion mixture upon the colorimetric determination. First, the amount of total phosphorus per hundred cubic centimeters of lake water is usually less than 0.0035 mg and second, part of the sulfuric is neutralized by the carbonate of the water and part is used in the digestion of the organic material.

Summary

The method for the determination of total phosphorus in lake water has been modified so that only one evaporation is required.

The effect of the sulfuric acid in the digestion mixture upon the intensity of the blue color, produced in the comparison with standards, has been noted.

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THE DETERMINATION OF KJELDAHL NITROGEN IN NATURAL WATERS[1]

REX J. ROBINSON AND GEORGE KEMMERER

Contribution from the Laboratory of Analytical Chemistry, University of Wisconsin, and Notes from the Biological Laboratory of the Wisconsin Geological and Natural History Survey. XXXVI.

In the study of the Wisconsin lakes the determination of the Kjeldahl or organic nitrogen in the water has proven important as it may be used as plant food, and from it and the organic carbon, the carbon-nitrogen ratios are calculated. The following work may also be applied to the determination of free ammonia although it is usually present in much smaller amounts and therefore of less interest.

In the Kjeldahl method as carried out in the field laboratory, the free ammonia is distilled from a 500 cc sample of the water. The remainder of the sample is then treated with 5 cc of concentrated sulfuric acid, and 5 grams of potassium sulfate, both ammonia free. The sample is then evaporated and digested until colorless, without the addition of oxidizing agents. The ammonia is then distilled from the diluted residue which has been made alkaline.

If collected in Nessler tubes and nesslerized, the first tube contains a large part of the ammonia which is usually too much to give a clear color. Dilution increases the error. In the early work the ammonia was collected in N/100 hydrochloric acid and the excess titrated with N/100 sodium hydroxide, using methyl red as an indicator. These results were satisfactory but the blank on the distilled water, due to the solution of alkali from the glass by the distilled water, had to be carefully prevented. For example, if the steam were not entirely condensed and cooled in the block tin condenser, the solution of glass from the collecting bottles introduced an error which sometimes amounted to 50% of the nitrogen present.

[1] Part of a thesis submitted by Rex J. Robinson in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

With careful work the titration method gave from known samples of ammonium chloride results which check to the third place of milligrams.

Mg. of Nitrogen as NH_4Cl	*Mg. of Nitrogen Obtained by Titration*
0.400	0.402
.400	.399
.150	.156
.150	.154
.050	.048
.050	.048

Using 500 cc water samples the following checks were obtained.

	Kjeldahl Nitrogen (p.p.m.)
Lake Wingra, Jan. 29, 1927	1.04
	1.03
Lake Mendota, Jan. 5, 1927	.50
	.52
Lake Monona, March 25, 1927	1.02
	1.02

In many cases these results did not agree with those obtained by collecting the distillate in Nessler tubes and nesslerizing. Smart gave data to indicate that only 85 to 95 per cent of the ammonia introduced in the distilling apparatus was regained when collected in Nessler tubes due to the loss of ammonia by imperfect condensation. Hazen and Clark found that there was no loss due to imperfect condensation, but that an apparent loss occurred if the temperature of the distillate were lower than that of the standard at the time of nesslerization. Their work was more or less qualitative in nature and did not give the losses with various concentrations of ammonia.

Standard Methods of Water Analysis states: "The temperature of both standards and prepared samples should be practically the same." They do not make it clear that the temperature should be the same before nesslerization and that equalization of the temperature after nesslerization has no effect. In discussing permanent standards the temperature of nesslerization is not mentioned although they mention the variation of the colors with the quality of the Nessler reagent and re-

quire comparison with nesslerized ammonia standards. The effect of the concentration of the ammonia on the nesslerization color at various temperatures has not been noted in the literature. The following series of nesslerizations were carried out with known amounts of ammonium chloride to determine the effect of the temperature at the time of nesslerization and the concentration of the ammonia present.

The determinations were carried out using 50-cc matched Nessler tubes. All were compared with standards nesslerized at 23° C and the other details were as specified in Standard Methods of Water Analysis.

Intensity of the Color of Nesslerized Ammonium Chloride Solutions at Various Temperatures and Concentrations

Temperature ° C.	*Mgs. Nitrogen as NH_4Cl*		*Appearance*
	Taken	*Increase*	
50	0.020	0.002	Clear
	0.050	0.008	Clear
	0.080	0.025	Cloudy
	0.100	0.057	Cloudy
	0.120	0.108	Cloudy
40	0.020	0.001	Clear
	0.050	0.003	Clear
	0.080	0.007	Clear
	0.100	0.014	Clear
	0.120	0.018	Cloudy
	0.150	0.027	Cloudy
	0.180	0.049	Cloudy
	0.200	0.068	Cloudy
30	0.020	0.001	Clear
	0.050	0.002	Clear
	0.080	0.001	Clear
	0.100	0.004	Clear
	0.120	0.004	Cloudy
	0.150	0.008	Cloudy
	0.180	0.008	Cloudy
	0.200	0.008	Cloudy
23	0.020	0.000	Clear
	0.050	0.000	Clear
	0.080	0.000	Clear
	0.100	0.002	Clear
	0.150	0.002	Cloudy
	0.200	0.000	Cloudy

Temperature ° C.	*Mgs. Nitrogen as NH_4Cl*		*Appearance*
	Taken	*Decrease*	
15	0.020	0.001	Clear
	0.050	0.001	Clear
	0.100	0.008	Clear
	0.150	0.013	Clear
	0.200	0.027	Clear
	0.250	0.036	Cloudy
10	0.020	0.002	Clear
	0.050	0.005	Clear
	0.100	0.015	Clear
	0.150	0.024	Clear
	0.200	0.034	Clear
	0.250	0.049	Clear
	0.300	0.056	Cloudy
1	0.020	0.001	Clear
	0.050	0.009	Clear
	0.100	0.019	Clear
	0.150	0.036	Clear
	0.200	0.048	Clear
	0.250	0.060	Clear
	0.300	0.084	Clear

The variation of the intensity of the color in terms of milligrams in the above table represents the average of two or more check determinations. These apparent losses or gains were plotted against the respective concentrations of nitrogen that had been used. All points for each temperature were connected, thus forming isothermal curves. (See fig. 1.) The curve for 23° C. merely indicates the accuracy of the estimation over this range of concentrations. The interval between any point on this curve and a point of a similar concentration on another curve for a temperature greater than 23° C. indicates the apparent gain in nitrogen. Likewise, the interval between a point of the curve at 23° C. and a point of a similar concentration on a curve at a lower temperature shows the apparent loss of nitrogen due to the smaller intensity of the nesslerization color for that temperature. Thus it was found that the further removed the temperature from 23° C. the greater the variation between the observed and the true values.

When a sufficiently large concentration of ammonia is used, a turbidity forms upon nesslerization which prevents accurate estimations. In the graph (fig. 1) a line (L) was drawn through the point on each curve which represents the concentration of nitrogen at which the first cloudiness appears at that temperature. Therefore, that portion of the graph above the line represents the cloudy nesslerized solutions while that below the line represents the clear solutions. Thus an increase in temperature above 23° C. causes a marked decrease in the amount of ammonia that may be nesslerized without cloudiness appearing, while at lower temperatures larger amounts may be accurately estimated, since, at these temperatures, the intensity of the color is less.

Therefore, these results prove that the temperature before nesslerization is important and must be the same as that of the standards for accurate work. The factor of temperature being carefully watched, accurate results may be obtained by collecting known amounts of ammonium chloride in Nessler tubes.

Milligrams of Nitrogen as Ammonium Chloride

Taken	*Recovered*
0.150	0.145
0.200	0.208
0.300	0.300
0.400	0.405
0.500	0.500

These data also show that there is no loss of ammonia by imperfect condensation even when large amounts of ammonia are used which are comparable to those found in the lake waters of

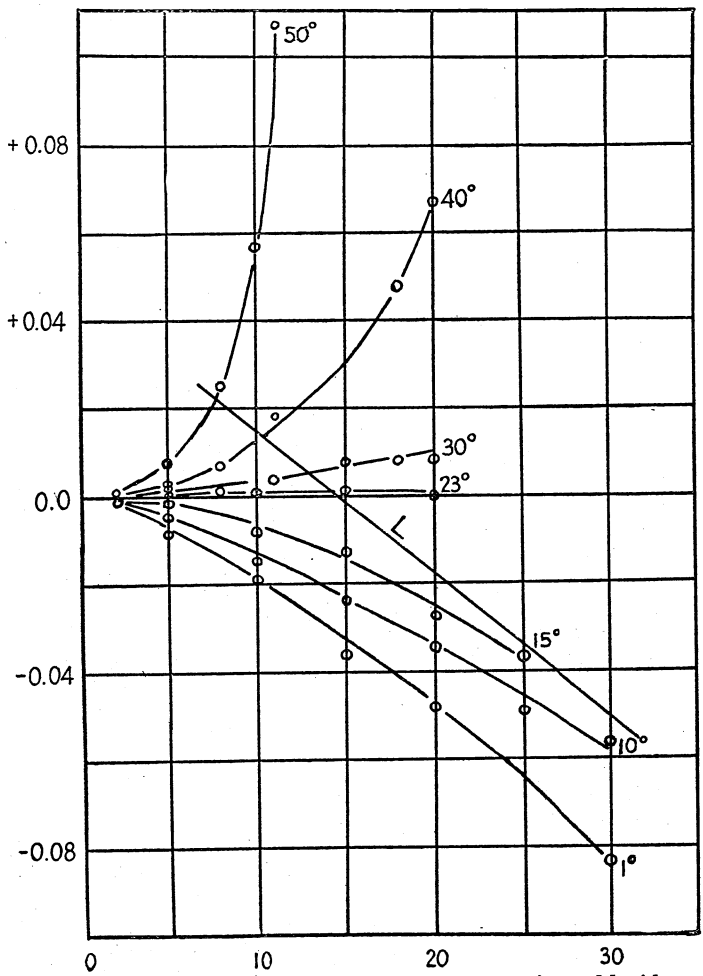

FIG. 1. Variation of color of nesslerized ammonium chloride solutions at various temperatures and concentrations. The abscissas represent the number of milligrams of nitrogen per 50 cc of solution and the ordinates the number of milligrams of nitrogen variation. The temperatures are indicated in degrees centigrade.

Wisconsin as organic nitrogen. Hazen and Clark (1890) stated that there was no loss of ammonia, but gave no data showing the quantities of ammonia that they used.

If the factors previously mentioned are watched carefully, check determinations may be obtained using either of the two methods of determination.

Comparison of Organic Nitrogen Results in Lake Waters by Titration and Nesslerization Procedures

	Organic Nitrogen (Mgs. per liter)	
	Titration	*Nesslerization*
Pauto	0.26	0.24
Clear	0.28	0.28
Big Carr	0.32	0.30
Mendota	0.51	0.49
Wingra	0.62	0.64

Although either of the methods should give accurate results when properly carried out, the factor of temperature was thought to be more easily controllable in routine work than preventing the solution of alkali from glass by the distilled water. Consequently the nesslerization procedure has been used, and with success, in the determination of Kjeldahl nitrogen in the Wisconsin lake waters.

Summary

1. Kjeldahl nitrogen in lake waters may be determined by the titration method using 0.01 N acid and base with methyl red as the indicator. However, the blank for alkali in distilled water must be carefully watched.

2. Data are given which add emphasis to the importance of maintaining equal temperatures for both standard and sample at the time of nesslerization.

3. No loss due to imperfect condensation was detected for amounts of ammonia comparable in size to the maximum amount found in lake water as organic nitrogen when the ammonia distillate was collected in Nessler tubes.

4. The nesslerization method was found to be preferable to the titration method for the routine determination of Kjeldahl nitrogen in the Wisconsin lake waters.

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DETERMINATION OF SILICA IN MINERAL WATERS[1]

REX J. ROBINSON AND GEORGE KEMMERER[2]

Contribution from the Laboratory of Analytical Chemistry, University of Wisconsin, and Notes from the Biological Laboratory of the Wisconsin Geological and Natural History Survey. XXXVII.

It has been known for many years that ammonium molybdate and sodium silicate, heated together in solution, produce a yellow colored silico molybdate, SiO_2. $12MoO_3$. One of the early reagents used in this reaction was that of Meillere, a solution of ammonium molybdate in a nitric sulfuric acid mixture. This reagent in the presence of dissolved silica slowly yields the characteristic yellow color even in the cold. However, on account of the low sensitivity of the reagent, low concentrations of silica such as those found in mineral waters could not be estimated by this method unless the sample was first concentrated by evaporation. This difficulty was eliminated by Diénert and Wandenbulcke (1923), who by omitting the nitric acid, increased the sensitivity of the molybdate reagent and made the reaction applicable to the determination of low concentrations of silica.

An examination of the methods described in the literature which depended on the silico molybdate color reaction for the determination of small amounts of silica revealed certain discrepancies in methods of standardization. A short outline of the procedure will serve to illustrate the point.

PROCEDURE

Measure 100 cc of the water to be tested, or a smaller amount diluted to 100 cc, into a graduated colorimeter or Nessler tube. Add 2 cc of a 10% ammonium molybdate solution and 4 drops of a 50% (by volume) sulfuric acid solution. The full intensity of the yellow color develops within 5 to 10 minutes, after which the color may be compared either with a standard sodium

[1] Part of a thesis submitted by Rex J. Robinson in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

[2] On account of the death of Professor Kemmerer in November 1928, this manuscript was prepared under the general direction of Professor V. W. Meloche.

silicate solution treated in the same manner as the unknowns, or preferably compared with diluted quantities of a standard picric acid solution, 1 cc of which is equivalent to 0.05 mg of SiO_2. The reagents for this procedure should be kept in Pyrex bottles to prevent extraction of silica from the glass.

The picric acid standard. The discrepancies in methods of standardization were particularly evident when one compared the various references to this reagent by different investigators. Diénert and Wandenbulcke (1923) found that 36.9 mgs of picric acid were equivalent to 50 mgs of SiO_2 determined by their colorimetric procedure. Thresh and Beale (1925) used 40 mgs of picric acid as being equivalent to 50 mgs of SiO_2. Finally, King and Lucas[3] (1928) considered both these values to be in error and indicated that 25.6 mgs of picric acid were equivalent to 50 mgs of SiO_2.

The purpose of the present investigation was to determine the source of these differences and to correct for them if possible.

Harmon (1927) found that the silica of sodium silicate, having a Na_2O/SiO_2 ratio less than unity, was estimatable by the colorimetric method only in very dilute solutions. In the more concentrated solutions part of the silica was in the colloidal state and was therefore unavailable for the colorimetric method of determination. It seemed quite probable that the disagreement of previous investigators might have resulted from a portion of the silica in their standard silicate solutions being in the colloidal form.

Picric acid standardized on sodium silicate whose Na_2O/SiO_2 ratio was less than unity. In order to determine the correct equivalency of the picric acid in terms of dissolved silica (not colloidal), a series of silicate solutions were prepared whose Na_2O/SiO_2 ratios ranged from 1/1 to 1/4. Before using these solutions, it was necessary to determine whether or not the ratio of colloidal to crystalloidal silica remained constant for a period of time. Assuming that the colorimetric method for silica essentially measured the silica in the crystalloidal state, appropriate samples of the standard silicate solutions were diluted to 100 cc and treated according to the procedure already

[3] The investigation described in the present paper was conducted before the publication of King and Lucas appeared and now serves to validate the claims of King and Lucas.

described. Standard picric acid solution was used as the basis of comparison, arbitrarily fixing 36.9 mgs of picric acid as being equivalent to 50 mgs of SiO_2. The amount of silica available colorimetrically did not differ in samples which were diluted and treated immediately with the molybdate reagent and in samples which were diluted and allowed to stand several days before the colorimetric estimation of silica was made. This seemed to indicate that the ratio between colloidal and crystalloidal silica in these solutions was constant.

It is important to note that the picric acid used as a standard in the colorimetric estimation of silica was obtained from several sources, the Wisconsin Organic Laboratory, the Merck Co., and the Baker Co. In each case the picric acid was dried before weighing, since some of the samples contained as much as 10% to 15% water. The drying was accomplished in a vacuum desiccator over sulfuric acid either at room temperature or at 65° C. In no case was there any detectable difference between any of the standard solutions prepared from these samples.

The total silica of the silicate solutions was determined by Harmon's gravimetric procedure in which 100 cc of the silicate solution was made acid with hydrochloric acid, evaporated to dryness in a platinum dish over a steam bath, and then baked at 130° C. The residue was moistened with hydrochloric acid, diluted to approximately 50 cc and the whole heated for about 15 minutes. The insoluble silica was filtered and washed with hot water. Additional silica was obtained from the filtrate by repeating this process. The filter papers were ignited and the amount of residual silica determined by volatilization with hydrofluoric acid.

The results of the gravimetric and colorimetric analyses are given in table 1.

TABLE 1—*Analyses of sodium silicate solutions. The results are expressed in milligrams of SiO_2 per 100 cc of solution*

Na_2O/SiO_2 ratio	*Gravimetrically*	*Colorimetrically*	*Percent colorimetrically*
1/1.58	55.9	37.2	67
1/2.00	68.2	40.0	59
1/2.40	50.0	27.6	55
1/2.84	55.8	29.3	52
1/3.25	49.6	23.5	47
1/3.86	35.1	14.0	39

The sodium silicate samples were obtained from the Philadelphia Quartz Co. and the Na_2O/SiO_2 ratios listed in column one were determined by the manufacturers and checked by Brouse (1927). Each analysis in columns two and three represents the mean of two or more check determinations. These results indicate that only part of the total SiO_2, when it is in excess of the Na_2O, is available for the colorimetric procedure; this is represented as percentage of the total amount, i. e. the amount of SiO_2 obtained gravimetrically, in column four.

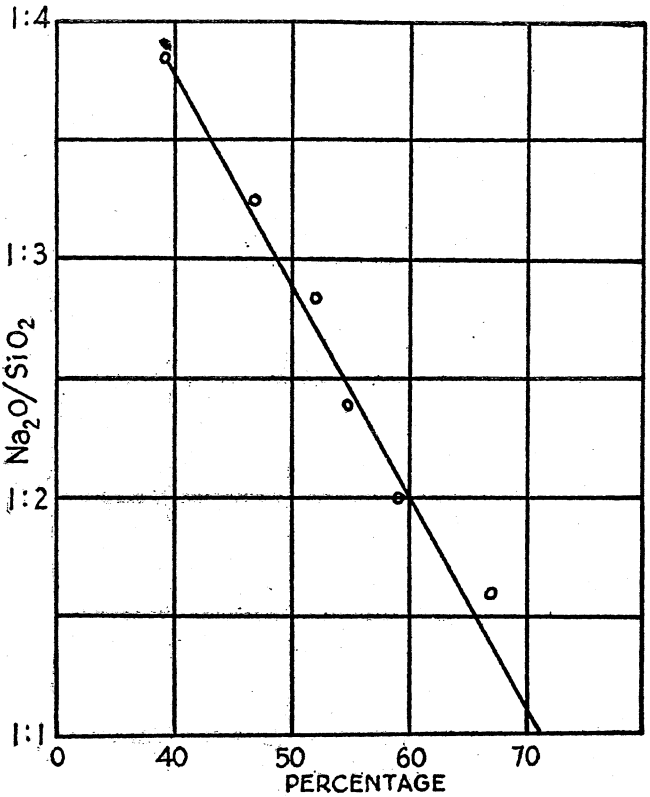

FIG. 1. Percentage of silica obtained by colorimetric method at various ratios of Na_2O/SiO_2.

If the Na_2O/SiO_2 ratio is plotted against the percentage of silica obtainable colorimetrically, the points so determined form a straight line. This fact indicates that the silica available colorimetrically is dependent upon the Na_2O/SiO_2 ratio, the

larger the excess of silica the smaller the percentage obtained colorimetrically. Even if a portion of the silica is unavailable colorimetrically when the SiO_2 is in excess of the Na_2O, all should be obtained either when the Na_2O is equivalent to or in excess of the SiO_2, since the silica is then entirely crystalloidal. However upon extrapolation to a ratio of one mole of Na_2O to one mole of SiO_2, only 72% of the silica is represented at this point as being available colorimetrically. This fact indicates that the picric acid standard is too concentrated. Thus instead of 36.9 mgs of picric acid being equivalent to 50 mgs of SiO_2 only 72% of 36.9 mgs (that amount having been used as standard for this work), which upon calculation is found to be 26.5 mgs, should be used.

Picric acid standardized on sodium silicate whose Na_2O/SiO_2 ratio is greater than unity. Since a portion of the silica in the sodium silicate standards was unobtainable by the colorimetric method when the Na_2O/SiO_2 ratio was less than unity, and also since the weight of picric acid as recommended for a permanent standard by previous investigators was probably in error, further study was deemed advisable, using a standard silicate solution having an excess of Na_2O.

0.25 mg of pure silica, previously dried in vacuum for several days, was fused in a platinum crucible with four to five times the theoretical amount of sodium carbonate required to give a ratio of one mole of Na_2O to one mole of SiO_2. After complete fusion the melt was dissolved in water and diluted to one liter. Using this standard solution, the strength of the picric acid standard, containing 36.9 mgs of vacuum-dried picric acid per liter of solution, was determined in terms of milligrams of SiO_2. Some typical results are listed below:

TABLE 2—*Amount of picric acid equivalent to 50 mgs. of silica*

Standard solution	*Milligrams of SiO_2 per cc of sodium silicate standard*	
	Present	*Found*
1	0.250	0.175
2	0.250	0.170
		0.172 Mean

Here again the data indicate that the picric acid standard is too concentrated and that 0.172/0.250 of the 36.9 mgs of the

picric acid is equivalent to 50 mgs of SiO_2. This amount upon calculation is found to be 25.4 mgs, which is in agreement with the value obtained by the graphical method, and is essentially the same as that recommended by King and Lucas who point out that 25.6 mgs of picric acid should be used. Also the graphical method is only an approximation in as much as the extrapolated value may vary within certain limits due to the uncertainty of the exact slope of the curve, consequently the value obtained by the fusion method is considered to be more nearly correct.

Summary

1. Two methods were given for the determination of the correct equivalency between picric acid and SiO_2 in the silico molybdate colorimetric determination of silica.

2. It was shown that 25.4 mgs of dry picric acid were equivalent to 50 mgs of silica (crystalloidal).

3. The value given was in reasonable agreement with that of King and Lucas who showed that 25.6 mgs of picric acid were equivalent to 50 mgs of silica.

Literature Cited

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MONTHLY RAINFALL MAPS OF WISCONSIN AND ADJOINING STATES

ERIC R. MILLER

Maps of the annual and semi-annual rainfall in Wisconsin and portions of the surrounding states were published in these Transactions last year. The maps of monthly rainfalls which follow have been constructed in the same way, except that one more year has been included in the averages, and eleven more observing stations have been added. The basic period is now the 32-years 1897–1928, and 215 reporting stations were used in making the maps.

In view of the great influence of topography upon the distribution of rainfall, there is now included in the series of maps, the topography as shown by 500-foot contour lines, copied from the map issued by the U. S. Geological Survey.

In order to ascertain the average rainfall of Wisconsin as a whole, the manuscript maps, scale 37 miles to 1 inch, were planimetered with the large Coradi integraph belonging to the Department of Mathematics of the University of Wisconsin. The areas between successive ¼ inch isohyets were measured separately. The results follow:

Month	*Average rainfall, inches*
January	1.10
February	1.15
March	1.86
April	2.49
May	3.73
June	4.19
July	3.98
August	3.56
September	3.82
October	2.67
November	1.77
December	1.27
Sum	31.59

The map of annual rainfall gave 31.37 inches. The difference, 0.22 inch, amounting to 0.7% (seven-tenths of one per cent), is small when it is remembered that about 100 separate areas were integrated, and also that the average rainfall of each area had to be estimated.

In addition to the maps, a table of the numerical averages for each station is included in this paper. Each station is subject to local peculiarities of topography, exposure of instruments, and methods of observing, that produce variations in the average rainfall. These variations can not be shown on the maps without introducing many small circles and irregularities. The latter were drawn on the manuscript maps, but have been smoothed away in the published maps. Since it is hoped that this paper will be of use to civil engineers, students, and others, it has been thought best to give the exact averages used in preparing the maps. As stated in the previous paper, these averages have been reduced to the basic period of 32 years, 1897–1928. The first column in the table shows the per cent of the 32 years that is represented by actual observations.

The following table shows the extent to which records were completed in the several states.

Number of stations in:

Percent complete	*Illinois*	*Iowa & Nebr.*	*Michigan*	*Minnesota*	*Wisconsin*	*Total*
100	3	23	4	13	18	61
96 to 99	11	30	--	18	11	70
91 to 95	1	1	2	4	11	19
81 to 90	3	--	8	--	7	18
71 to 80	--	--	6	1	8	15
61 to 70	--	--	--	1	10	11
51 to 60	1	--	1	--	9	11
41 to 50	--	--	--	--	5	5
31 to 40	--	--	1	--	2	3
21 to 30	--	--	1	--	1	2
Total	19	54	23	37	82	215

The following additions to the bibliography and cartography of the rainfall of Wisconsin and adjoining states given in these Transactions, Vol. 24, p. 504, may be of interest.

Martin, Lawrence, Physical Geography of Wisconsin, Wis. Geol. & Nat. Hist. Surv. Bull. No. 36, Madison, 1916. Fig. 5,

page 16 "Rainfall in Wisconsin", although referred to in the text as the mean annual rainfall, is the rainfall of the year 1903 only. Cf. map on page 11, Annual Summary, 1903, Wisconsin Section of the Climate and Crop Service of the Weather Bureau.

Mead, Daniel W. Hydrology, N. Y. 1919. Fig. 114, p. 207 "Mean annual rainfall in Wisconsin, 1895–1918".

Reed, Charles D. "Iowa normal precipitation maps, monthly and annual," pp. 84–97. Annual Rep't for 1927, Iowa Weather and Crop Bureau. Reprinted from Part 26 of 28th Annual Iowa Yearbook of Agriculture. Des Moines, 1928.

Average precipitation in Wisconsin and adjacent states for the 32 years, 1897 to 1928 inclusive

Station	% obs'd	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Apr.—Sept.	%
NORTHERN ILLINOIS																
Aledo	88	1.35	1.43	2.40	3.04	4.17	4.27	3.39	3.19	4.35	2.45	1.97	1.35	33.36	22.41	67
Aurora	99	1.75	1.67	2.75	2.74	4.01	4.02	3.37	3.38	3.90	2.64	2.28	1.70	34.22	21.42	63
Chicago	100	1.80	1.83	2.76	2.63	3.30	3.25	3.20	3.36	3.31	2.33	2.16	1.89	31.81	19.05	60
Dixon	99	1.41	1.42	2.63	2.90	4.11	3.82	3.95	3.47	3.85	2.65	1.85	1.46	33.53	22.10	66
Dwight	90	1.99	1.75	2.85	3.19	3.83	3.65	2.99	3.34	3.56	2.32	2.29	1.85	33.63	20.56	61
Freeport	59	1.34	1.37	2.40	2.97	4.15	4.29	4.22	4.05	4.02	2.78	1.95	1.48	35.02	23.70	68
Galva	100	1.50	1.54	2.82	3.02	4.15	3.93	3.60	3.67	4.03	2.32	2.06	1.40	34.05	22.40	66
Henry	97	1.79	1.67	2.93	3.21	3.86	4.12	3.10	3.48	4.22	2.44	2.27	1.58	34.66	21.99	63
Joliet	99	1.80	1.58	2.71	2.85	3.74	3.78	3.32	3.20	3.66	2.47	2.25	1.80	33.15	20.55	62
Marengo	98	1.54	1.47	2.50	2.79	3.43	3.98	3.21	3.55	3.80	2.50	2.00	1.58	32.37	20.76	64
Minonk	96	1.68	1.65	2.60	3.13	3.68	3.77	3.08	3.46	3.87	2.38	2.08	1.64	33.01	20.99	64
Monmouth	99	1.69	1.59	2.56	3.14	3.89	4.33	3.77	3.13	4.50	2.40	2.13	1.46	34.58	22.76	66
Morrison	100	1.41	1.58	2.62	3.06	4.23	4.08	3.87	3.67	3.85	2.45	1.92	1.49	34.23	22.76	66
Mt. Carroll	97	1.30	1.31	2.18	2.85	4.09	4.10	3.58	4.09	4.34	2.55	2.10	1.49	33.98	23.06	68
Ottawa	92	1.80	1.74	2.75	2.90	4.11	3.39	3.16	3.73	3.98	2.33	2.21	1.59	33.70	21.27	63
Rockford	87	1.58	1.60	2.60	2.83	3.78	3.84	3.45	3.57	3.75	2.61	2.05	1.51	33.18	21.22	64
Sycamore	99	1.45	1.58	2.93	2.96	3.82	3.87	3.30	3.79	3.81	2.88	2.14	1.61	34.16	21.55	63
Tiskilwa	99	1.66	1.73	3.01	3.15	4.14	3.78	3.13	3.65	4.02	2.51	2.30	1.58	34.67	21.87	63
Walnut	99	1.61	1.68	2.77	2.84	3.95	3.86	3.33	3.71	4.35	2.43	2.01	1.50	34.06	22.04	65
IOWA																
Afton	100	.84	1.16	2.00	3.34	4.58	4.93	3.57	3.74	4.45	2.57	1.37	1.05	33.61	24.61	73
Albia	97	1.08	1.37	2.00	3.08	4.47	4.74	3.89	3.55	4.25	2.34	1.60	1.07	33.43	23.98	72
Algona	100	.76	1.05	1.43	2.73	4.48	4.28	3.06	4.03	4.11	2.15	1.48	.95	30.51	22.69	74
Alta	100	.71	1.03	1.51	2.77	4.69	4.56	3.91	3.61	3.72	2.04	1.50	.91	30.96	23.26	75
Ames	96	.69	.94	1.37	2.85	4.46	4.16	3.22	3.77	4.32	2.69	1.29	1.03	30.77	22.78	74
Atlantic	99	.82	1.15	1.62	2.77	3.75	4.97	3.45	3.86	4.01	2.46	1.47	1.06	31.38	22.81	73
Belle Plain	99	1.35	1.56	2.33	3.32	4.58	4.69	4.16	3.71	4.38	2.49	1.80	1.38	35.75	24.84	70
Bonaparte	100	1.38	1.29	2.14	3.00	4.02	5.00	3.87	3.59	4.39	2.31	1.75	1.12	33.86	23.87	70
Carroll	100	.72	1.04	1.50	2.60	4.14	4.82	3.39	4.49	4.33	2.46	1.32	.96	31.77	23.77	75
Cedar Rapids	98	.94	1.20	1.68	2.64	3.91	4.01	3.58	3.85	3.91	2.19	1.39	1.06	30.36	21.90	72
Charlton	99	.94	1.18	1.79	3.14	3.95	4.75	3.92	3.57	4.39	2.46	1.48	1.02	32.59	23.72	73
Charles City	100	.95	1.18	1.79	2.45	4.54	4.30	3.86	4.13	3.78	2.29	1.60	1.18	32.05	23.06	72
Clarinda	100	.86	1.22	1.68	2.88	4.16	4.69	4.12	3.63	4.64	2.77	1.55	1.10	33.30	24.12	72
Clinton	99	1.49	1.63	2.72	2.96	4.02	4.21	3.72	4.07	4.26	2.59	2.01	1.56	35.25	23.24	66
Corning	99	.87	1.18	1.90	2.93	4.34	4.75	3.94	3.83	4.39	2.80	1.52	1.11	33.56	24.18	72
Corydon	99	1.12	1.35	2.07	3.33	4.20	5.11	3.82	3.46	4.68	2.62	1.60	1.25	34.62	24.60	71
Davenport	100	1.37	1.48	2.47	2.83	3.65	4.02	3.23	3.64	3.86	2.21	1.79	1.37	31.94	21.23	66
Decorah	99	1.12	1.13	1.87	2.60	4.41	4.09	3.92	3.95	4.08	2.53	1.86	1.23	32.79	23.05	70

Average precipitation in Wisconsin and adjacent states for the 32 years, 1897 to 1928 inclusive—Continued

Station	% obs'd	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov	Dec.	Year	Apr.—Sept.	%
Denison	97	.62	.89	1.28	2.46	3.99	4.19	3.51	3.94	3.53	2.22	1.32	.78	28.72	21.62	75
Des Moines	100	.93	1.15	1.87	2.94	4.31	4.45	3.40	3.74	3.88	2.20	1.38	1.10	31.36	22.72	72
Dubuque	100	1.10	1.28	2.01	2.70	4.11	3.89	3.61	3.62	3.91	2.38	1.63	1.24	31.47	21.84	69
Fayette	97	1.10	1.44	2.16	2.86	4.79	4.29	4.27	4.02	4.28	2.50	1.86	1.32	34.89	24.51	70
Forest City	100	.86	1.04	1.41	2.25	4.34	4.36	3.39	3.58	3.64	2.31	1.47	.91	29.57	21.56	73
Grinnell	97	1.09	1.18	1.87	3.35	4.32	4.78	4.18	3.92	4.50	2.46	1.61	1.06	34.32	25.05	73
Grundy Center	97	.93	1.00	1.77	2.88	4.66	5.05	3.55	4.13	4.34	2.68	1.58	1.11	33.66	24.61	73
Guthrie Center	95	.83	1.15	1.61	2.75	4.12	4.64	3.82	4.01	3.99	2.50	1.42	1.09	31.92	23.33	73
Humboldt	96	.80	1.02	1.50	2.41	4.19	4.42	3.46	3.66	3.66	2.23	1.65	.79	29.77	21.80	73
Independence	98	.87	.94	1.56	2.52	4.23	4.40	3.74	3.78	3.84	2.47	1.59	1.14	31.07	22.51	72
Indianola	97	1.06	1.28	1.65	3.00	4.14	4.52	3.40	3.91	3.98	2.33	1.65	1.14	32.07	22.95	72
Iowa City	100	1.31	1.40	2.34	3.08	4.56	4.50	3.78	3.91	4.13	2.60	1.83	1.41	34.85	23.96	69
Iowa Falls	100	1.03	1.40	1.81	2.62	4.15	4.46	3.33	3.82	4.02	2.45	1.53	1.14	31.76	22.40	71
Keokuk	100	1.53	1.32	2.52	2.94	3.86	4.24	3.33	3.24	4.33	2.21	1.92	1.37	32.81	21.94	67
Keosauqua	99	1.47	1.48	2.32	3.00	4.18	5.23	4.19	3.52	4.27	2.50	1.84	1.38	35.37	24.39	69
Le Mars	97	.54	.78	1.25	2.61	4.28	4.12	3.92	2.98	3.50	1.74	1.17	.76	27.65	21.41	77
Logan	99	.71	.97	1.40	2.62	3.65	4.69	3.44	3.82	3.37	2.09	1.52	.92	29.20	21.59	74
Marshalltown	98	1.08	1.18	2.00	2.90	4.12	4.68	3.71	3.36	4.72	2.62	1.57	1.12	33.07	23.49	71
Mt. Ayr	100	.95	1.28	1.97	3.30	4.62	5.05	4.46	3.68	4.58	2.69	1.70	1.16	35.44	25.69	72
Mt. Pleasant	99	1.39	1.35	2.39	3.22	4.04	4.92	3.97	3.42	4.42	2.26	1.88	1.39	34.66	23.99	69
Muscatine	99	1.61	1.66	2.33	3.01	3.98	4.14	3.33	4.05	3.97	2.33	1.92	1.47	33.81	22.48	66
Northwood	96	.98	1.31	1.78	2.66	4.82	4.75	3.57	4.05	4.17	2.45	1.78	1.22	33.55	24.02	72
Oskaloosa	99	1.02	1.26	2.02	2.92	3.78	4.41	3.75	3.51	4.08	2.36	1.60	1.23	31.94	22.45	70
Postville	100	1.09	1.22	1.85	2.75	4.77	4.32	4.43	3.96	4.20	2.67	1.75	1.21	34.22	24.43	71
Sigourney	98	1.15	1.42	2.22	3.08	3.86	4.66	3.82	3.23	4.15	2.42	1.70	1.30	33.00	22.08	69
Sioux City	100	.61	.89	1.15	2.39	3.94	3.75	3.30	3.08	3.26	1.70	1.02	.83	25.92	19.72	76
Thurman	100	.69	1.30	1.60	3.10	4.46	5.16	4.04	4.27	4.45	2.59	1.74	1.13	34.53	25.48	74
Washington	99	1.30	1.49	2.33	3.22	3.77	4.19	3.61	3.93	4.30	2.45	1.77	1.31	33.68	23.02	68
Washta	99	.62	.86	1.17	2.71	4.23	4.73	3.87	3.29	3.61	1.91	1.29	.83	29.12	22.44	77
Waterloo	100	.94	1.20	1.86	2.48	4.10	4.34	3.84	3.78	4.04	2.49	1.57	1.13	31.77	22.58	71
West Bend	98	.75	.94	1.32	2.56	4.01	4.25	3.37	3.77	3.46	1.97	1.40	.95	28.74	21.42	75
Winterset	97	.83	1.14	1.77	3.27	3.88	4.67	3.89	3.67	3.89	2.46	1.53	1.05	32.04	23.27	73
MICHIGAN, UPPER PENINSULA																
Calumet	100	2.73	1.67	1.68	2.07	3.09	3.44	3.17	3.10	3.96	3.08	2.65	3.20	33.83	18.83	56
Chatham	78	1.93	1.74	1.78	2.14	2.78	3.58	3.64	2.98	3.90	3.36	2.74	2.10	32.67	19.02	58
Deer Park	79	2.31	1.96	1.76	1.71	2.92	2.88	2.86	2.32	3.30	2.63	2.44	3.02	30.11	15.99	54
Eagle Harbor	82	1.81	1.66	1.88	2.04	2.62	3.04	2.96	2.80	3.14	2.48	2.38	2.19	29.00	16.60	57
Escanaba	100	1.28	1.40	2.07	2.32	2.59	2.88	3.70	3.09	3.09	2.43	1.98	1.48	28.31	17.67	62
Ewen	79	1.82	1.62	2.10	2.06	2.86	3.24	3.37	2.64	3.19	2.10	2.40	2.26	29.66	17.36	59
Grand Marais	80	2.78	2.00	1.95	1.98	2.39	2.85	2.64	2.38	3.26	2.96	2.60	2.72	30.51	15.50	51

Average precipitation in Wisconsin and adjacent states for the 32 years, 1897 to 1928 inclusive—Continued

Station	% obs'd	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Apr.—Sept.	%
MICHIGAN																
Houghton	84	2.34	1.64	1.96	2.20	2.96	2.90	3.38	2.57	3.51	2.78	2.75	2.80	33.75	19.48	58
Humboldt	88	1.22	1.08	1.51	1.88	2.44	3.09	3.59	3.07	3.75	2.45	2.17	1.40	27.67	17.82	64
Iron Mountain	89	.84	1.07	1.59	2.39	2.87	3.68	4.23	3.36	3.28	2.43	1.72	1.20	28.66	19.81	69
Iron River	94	1.22	1.38	2.19	2.90	3.42	4.27	4.43	3.68	3.91	2.94	1.99	1.59	33.91	22.61	67
Ironwood	82	1.84	1.70	2.46	2.49	2.84	3.78	4.48	3.22	3.64	2.68	2.44	2.34	33.91	20.45	60
Ishpeming	90	1.50	1.46	2.08	2.32	2.94	3.18	3.83	3.10	3.84	2.98	2.37	1.52	31.12	19.21	62
Mackinac Id.	75	1.99	1.42	2.30	2.44	3.15	2.99	2.91	2.96	3.52	3.26	2.33	1.76	31.03	17.97	58
Marquette	100	2.20	1.74	2.33	2.51	2.89	3.37	3.37	2.66	3.23	2.59	2.72	2.38	31.98	18.03	56
Munising	93	2.26	1.71	1.90	2.24	2.74	2.90	3.25	2.65	3.74	3.14	3.12	2.51	32.17	17.52	54
Newberry	85	1.72	1.42	1.81	1.79	2.70	2.74	2.78	2.57	2.93	2.64	2.27	1.72	27.08	15.51	57
Sack Bay	25	1.84	2.08	3.00	2.73	3.43	3.40	3.36	2.73	3.42	3.32	2.60	1.90	33.81	19.07	56
St. Ignace	73	1.59	1.18	1.89	1.88	2.46	2.42	2.78	2.45	2.80	2.58	2.13	1.70	25.81	14.79	57
S. Ste. Marie	100	1.60	1.19	1.72	2.12	2.52	2.61	2.81	2.82	3.32	3.04	2.61	2.05	28.41	16.20	57
Seney	34	1.35	.75	1.29	1.56	2.81	2.65	2.98	2.25	3.03	2.22	1.72	1.38	23.99	15.28	64
Sidnaw	54	1.46	1.51	1.54	1.56	2.52	3.69	3.56	2.94	4.32	2.46	1.80	1.36	28.72	18.59	65
Whitefish Pt.	82	2.36	1.88	2.15	2.14	3.02	2.84	2.98	2.61	3.84	3.39	3.23	3.14	33.58	17.43	52
MINNESOTA																
Albert Lea	98	.83	.94	1.34	2.29	4.21	4.52	3.46	3.74	3.92	2.18	1.33	.98	29.75	22.14	74
Alexandria	99	.59	.52	.92	1.63	3.08	4.05	3.68	3.47	2.57	1.70	.85	.55	23.63	18.48	78
Bird Island	100	.63	.64	1.14	1.87	3.06	4.60	3.18	3.43	2.93	1.84	.94	.62	24.88	19.07	74
Campbell	96				2.06	2.73	4.01	3.29	2.92	2.75					17.76	
Collegeville	100	.65	.61	1.08	1.69	2.95	4.01	3.61	3.10	2.81	1.74	1.01	.60	23.85	18.17	76
Crookston	99	.58	.61	.87	1.68	2.76	3.54	3.36	2.83	2.22	1.44	.65	.73	21.26	16.39	77
Detroit Lakes	99	.61	.73	.88	1.80	3.19	4.35	3.94	3.72	2.80	1.77	.79	.66	25.23	19.80	78
Duluth	100	1.00	1.00	1.52	1.78	2.85	3.85	3.98	3.20	3.23	2.24	1.36	1.05	27.05	18.89	70
Fairmont	99	.77	1.01	1.41	2.36	4.06	4.56	3.75	3.62	3.57	1.85	1.43	.89	29.29	21.92	75
Farmington	95	1.00	.86	1.48	2.13	3.15	3.99	3.42	3.37	3.38	2.51	1.34	.90	27.51	19.44	71
Fergus Falls	100	.84	.78	1.04	1.98	2.98	4.36	3.65	3.10	2.79	1.68	.94	.83	24.97	18.86	75
Fort Ripley	69	.48	.55	.68	1.56	2.92	5.22	3.27	3.32	2.64	1.88	.98	.50	24.00	18.93	79
Grand Meadow	100	.91	1.11	1.87	2.48	4.70	4.99	4.02	4.10	4.15	2.61	1.61	1.15	33.71	24.44	73
Leech Lake Dam	99	.70	.66	1.13	1.66	2.94	4.08	3.82	4.20	3.00	2.01	1.08	.81	26.08	19.70	76
Lynd	98	.69	.79	1.13	2.28	3.30	4.16	2.93	3.45	2.70	1.78	.99	.65	24.85	18.82	76
Milan	99	1.06	.86	1.14	1.95	3.01	4.03	3.17	3.17	2.31	1.63	.94	.89	24.18	17.64	73
Montevideo	97	.73	.69	1.16	2.03	3.15	4.27	3.09	3.25	2.65	1.72	1.07	.69	24.50	18.44	75
Moorhead	100	.66	.65	.98	1.99	2.81	3.84	3.41	3.07	2.32	1.52	.83	.72	22.80	17,44	76
Mora	75	.81	.93	1.36	1.92	3.43	4.02	4.06	3.57	3.42	2.35	1.37	.83	28.07	20.42	73
Morris	99	.78	.70	1.02	2.02	3.16	4.25	3.68	3.06	2.49	1.60	.87	.67	24.30	18.66	77
New London	99	.55	.49	.93	1.61	2.67	4.09	3.72	3.10	2.68	1.69	.82	.51	22.87	17.87	78
New Ulm	100	1.22	1.10	1.65	2.34	3.72	5.43	3.89	3.96	3.77	2.27	1.26	.99	31.58	23.11	73

Average precipitation in Wisconsin and adjacent states for the 32 years, 1897 to 1928 inclusive—Continued

Station	% obs'd	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Apr.—Sept.	%
Park Rapids	99	.65	.62	1.01	1.84	2.92	4.33	3.84	3.72	2.79	1.87	.97	.69	25.27	19.44	77
Pine River Dam	100	.59	.63	1.04	1.92	3.19	4.70	3.94	3.79	3.15	2.36	1.01	.59	26.91	20.69	77
Pokegama Falls	100	.58	.57	1.05	1.54	2.82	3.90	3.85	3.66	3.02	1.98	1.06	.66	24.69	18.79	76
Red Wing	92	1.00	1.15	1.44	2.12	3.72	4.43	3.47	3.63	3.96	2.68	1.59	.98	30.17	21.33	71
Reeds	94	.66	.71	1.23	2.05	3.77	4.46	3.63	3.86	4.09	2.52	1.35	.92	29.25	21.86	75
St. Cloud	97	.79	.67	1.21	1.97	3.39	4.65	4.01	3.49	3.50	2.19	1.18	.56	27.62	21.01	76
St. Paul	100	.88	.91	1.44	2.10	3.27	4.41	3.55	3.27	3.18	2.43	1.30	.88	27.62	19.78	72
St. Peter	97	.84	.67	1.14	1.98	3.41	5.00	3.49	3.63	3.50	2.25	1.16	.71	27.78	21.01	76
Sandy Lake Dam	100	.65	.60	1.04	1.64	3.00	4.09	4.19	3.71	3.03	1.97	1.08	.67	25.66	19.66	77
Two Harbors	100	.67	.81	1.08	1.64	2.90	3.86	3.86	3.33	3.76	2.18	1.41	.77	26.26	19.35	74
Virginia	99	.80	.77	1.10	1.53	2.75	4.04	4.20	3.78	3.69	2.18	1.14	1.01	26.98	19.99	74
Winnebago	99	.77	.93	1.31	2.39	3.96	4.81	3.71	3.61	3.49	2.03	1.27	.85	29.12	21.97	75
Winnebigoshish	100	.64	.59	.99	1.68	2.85	4.10	3.69	4.18	3.03	1.82	1.04	.72	25.33	19.53	77
Winona	95	.89	.97	1.68	2.32	4.16	4.85	4.00	3.73	3.88	2.58	1.44	1.08	31.58	22.94	73
Worthington	97	.56	.81	1.32	2.10	3.86	4.47	3.56	3.82	3.36	1.72	1.04	.64	27.27	21.17	78
NEBRASKA																
Ashland	100	.51	.84	.97	2.37	3.65	4.42	3.84	3.30	3.37	1.82	1.18	.82	27.09	20.95	77
Blair	100	.54	1.00	1.37	2.60	4.24	4.72	3.67	3.48	3.19	2.10	1.44	.95	29.31	21.90	75
Fremont	100	.59	1.01	1.44	2.70	4.02	4.96	3.71	4.16	3.03	1.96	1.37	.96	29.90	22.58	76
Omaha	100	.64	.94	1.24	2.18	3.17	4.12	3.12	2.94	3.47	1.97	1.16	.89	25.84	19.00	74
WISCONSIN																
Antigo	62	.77	1.02	1.78	2.38	3.63	4.48	4.50	3.28	3.96	2.80	1.50	1.00	31.10	22.23	71
Appleton	61	1.16	1.42	2.10	2.50	3.51	3.63	4.36	2.92	3.75	2.34	1.85	1.34	30.88	20.67	67
Ashland	99	.92	.99	1.23	1.97	3.04	3.70	4.16	3.11	3.36	2.30	1.46	1.17	27.41	19.34	70
Barron	71	1.08	.98	1.54	2.16	3.68	4.67	4.22	3.66	3.52	2.56	1.64	.88	30.59	21.91	72
Beloit	98	1.42	1.39	2.31	2.78	3.63	3.92	3.66	3.43	3.90	2.47	1.90	1.54	32.36	21.32	66
Big St. Germain Dam	59	.94	.93	1.54	2.14	3.06	3.88	4.42	3.78	3.88	2.74	1.76	1.22	30.29	21.16	70
Brodhead	95	1.29	1.52	2.31	2.96	3.66	4.21	3.83	3.70	4.12	2.61	1.99	1.62	33.83	22.48	66
Burnett	78	.98	1.06	1.44	2.42	3.79	4.04	2.96	3.28	3.60	2.45	1.88	1.20	29.10	20.09	69
Chilton	37	1.52	1.54	2.02	2.58	3.83	3.98	3.33	3.04	3.70	2.30	1.92	1.67	31.43	20.46	65
Cornucopia	49	.95	.86	1.16	1.84	2.74	3.64	3.42	3.15	3.32	2.38	1.48	1.38	26.32	18.11	69
Darlington	92	1.23	1.37	2.03	3.04	4.19	4.35	3.87	4.01	4.46	2.74	1.99	1.43	34.69	23.92	69
Deerskin Dam	58	.86	.87	1.54	1.96	3.24	4.02	4.46	3.96	3.87	2.86	1.77	1.19	30.60	21.51	70
Downing	90	1.23	.99	1.39	1.99	3.63	5.06	4.22	3.74	3.72	2.96	1.44	1.01	31.41	22.36	71
Eau Claire	100	1.09	1.16	2.08	2.38	4.22	4.80	3.71	3.77	4.05	2.99	1.74	1.18	33.16	22.93	69
Florence	95	1.07	1.32	1.88	2.41	2.89	3.88	4.54	3.52	3.51	2.45	1.96	1.27	30.71	20.75	68
Fond du Lac	100	1.25	1.23	1.81	2.51	3.61	3.58	3.15	3.73	3.61	2.55	2.01	1.37	30.43	20.19	66
Grand River Locks	100	.97	1.09	1.87	2.57	4.24	4.16	3.66	3.75	4.00	2.70	1.97	1.23	32.21	22.38	69

Average precipitation in Wisconsin and adjacent states for the 32 years, 1897 to 1928 inclusive—Continued

Station	% obs'd	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Apr.—Sept.	%
Grantsburg	98	.94	.99	1.38	2.15	3.36	4.80	4.71	3.27	3.72	2.54	1.53	.99	30.36	22.01	72
Green Bay	100	1.11	1.32	2.11	2.65	3.46	3.57	3.49	3.00	3.33	2.27	1.79	1.30	29.37	19.50	66
Hancock	95	1.03	1.18	1.70	2.70	4.24	4.55	3.54	3.50	3.84	2.47	1.61	1.27	31.63	22.37	71
Hatfield	91	.90	1.02	1.55	2.47	4.11	4.56	4.13	3.49	3.80	2.60	1.61	1.18	31.42	22.56	72
Hayward	93	.98	.99	1.49	1.77	3.19	4.30	4.17	3.52	3.41	2.69	1.39	.89	28.79	20.36	71
High Falls	53	1.20	1.57	2.24	2.61	3.22	3.75	4.47	3.81	3.70	2.56	1.80	1.50	32.43	21.56	66
Hillsboro	100	1.15	1.20	1.81	2.86	4.32	4.45	3.87	3.66	4.14	2.46	1.82	1.35	33.07	23.30	70
Iron River	54	.92	.92	1.36	2.03	3.13	3.85	4.10	3.16	3.46	2.46	1.44	1.17	28.00	19.73	70
Kewaunee	48	1.48	1.56	1.93	2.64	3.46	3.14	3.21	2.84	3.10	2.40	2.10	1.60	29.46	18.39	62
Koepenick	83	1.12	1.17	1.73	2.50	3.44	4.10	4.36	3.69	4.28	2.83	1.89	1.23	32.33	22.37	69
La Crosse	100	.98	1.13	1.74	2.39	4.02	4.20	3.75	3.91	3.88	2.33	1.62	1.26	31.20	22.15	71
Lake Mills	99	1.24	1.23	1.97	2.92	4.15	3.79	3.75	3.75	4.03	3.05	2.13	1.42	33.42	22.39	67
Lancaster	88	.91	1.17	1.94	2.88	4.12	4.13	4.02	3.62	3.93	2.47	1.82	1.24	32.25	22.70	70
Long Lake	66	.88	.98	1.70	2.20	2.95	3.76	3.92	3.56	3.46	2.57	1.72	1.05	28.75	19.85	69
Madison	100	1.17	1.33	2.03	2.62	3.85	3.36	3.50	3.33	3.91	2.29	1.77	1.40	30.55	20.57	67
Manitowoc	100	1.37	1.57	2.30	2.61	3.54	3.34	3.60	2.98	3.53	2.72	2.22	1.73	31.51	19.60	62
Marshfield	49	1.17	1.01	1.67	2.72	4.04	4.54	4.08	3.92	3.76	3.02	2.07	1.38	33.38	23.06	69
Mather	76	1.04	1.20	1.66	2.55	4.30	4.42	4.10	3.74	4.02	2.58	1.74	1.13	32.48	23.13	71
Mauston	82	1.03	1.12	1.76	2.69	4.42	4.27	3.94	3.43	3.88	2.36	1.77	1.11	31.78	22.63	71
Meadow Valley	100	.82	.86	1.43	2.36	3.87	4.30	3.92	3.54	4.19	2.46	1.60	1.06	30.41	22.18	73
Medford	100	.85	.94	1.56	2.45	3.92	4.98	4.58	3.99	4.28	3.24	1.72	1.01	33.50	24.20	72
Menasha	100	.98	1.11	1.61	2.29	3.40	3.51	3.38	2.85	3.64	2.35	1.61	1.17	27.88	19.07	68
Merrill	69	.86	1.02	1.71	2.46	3.54	4.25	4.74	3.56	3.92	3.02	1.81	1.22	32.11	22.47	70
Milwaukee	100	1.66	1.69	2.50	2.61	3.33	3.14	2.59	2.86	3.56	2.52	1.79	1.65	29.91	18.09	60
Minocqua	76	.78	.90	1.56	2.17	3.18	4.00	4.82	3.84	4.02	2.66	1.65	.94	30.52	22.03	72
Mondovi	61	.97	1.08	2.08	2.32	4.21	5.39	4.02	3.56	4.12	2.69	1.46	1.22	33.12	23.62	71
Mt. Horeb	50	1.19	1.14	2.12	3.00	4.26	4.28	4.08	3.56	3.96	2.65	1.96	1.38	33.58	23.14	69
Muscoda	29	.79	1.11	1.92	2.57	4.07	3.92	3.62	3.90	4.08	2.30	1.86	1.23	31.37	22.16	71
Neillsville	98	1.03	1.20	1.95	2.66	4.15	4.77	3.99	3.77	4.09	2.78	1.69	1.35	33.42	23.43	70
New London	100	1.17	1.41	2.24	2.82	4.08	4.38	4.10	3.57	3.79	2.50	2.05	1.45	33.57	22.74	68
New Richmond	40	1.10	1.16	1.90	1.65	3.26	5.38	3.81	2.94	3.43	2.53	1.70	1.13	29.99	20.47	68
Oconto	97	1.41	1.46	1.96	2.67	3.58	3.50	3.77	3.16	3.44	2.58	1.92	1.57	31.01	20.12	65
Osceola	74	.99	.92	1.53	1.80	3.56	4.64	4.08	3.32	3.94	2.69	1.38	.96	29.81	21.34	72
Oshkosh	94	1.14	1.11	1.82	2.73	3.59	3.90	3.45	3.24	3.48	2.26	1.91	1.23	29.86	20.39	68
Park Falls	93	1.22	1.15	1.82	2.33	3.25	4.46	4.75	4.12	4.14	2.85	1.83	1.35	33.27	23.05	69
Pine River	100	1.08	1.30	2.02	2.75	4.06	4.09	3.77	3.40	3.83	2.47	1.92	1.39	32.07	21.90	68
Plum Island	62	1.50	1.34	2.12	2.12	3.04	2.66	3.32	3.00	3.02	2.54	2.48	1.54	28.68	17.16	60
Plymouth	59	1.18	1.52	2.03	2.52	3.36	3.18	2.80	3.39	3.48	2.86	2.23	1.40	29.95	18.73	63
Portage	100	.89	1.08	1.85	2.81	3.93	3.95	3.64	3.82	3.95	2.59	1.83	1.34	31.68	22.10	70
Port Washington	97	1.76	1.85	2.57	2.87	3.77	3.18	2.89	3.03	3.50	2.58	2.12	1.78	31.90	19.24	60

Average precipitation in Wisconsin and adjacent states for the 32 years, 1897 to 1928 inclusive—Continued

Station	% obs'd	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Apr.—Sept.	%
Prairie du Chien	100	.94	1.13	1.87	2.41	3.99	4.22	3.80	4.00	3.99	2.34	1.72	1.24	31.66	22.41	71
Prairie du Sac	57	.91	.94	1.50	2.36	3.75	3.64	3.36	3.48	3.87	1.95	1.39	.98	28.13	20.46	73
Prentice	92	1.03	.92	1.64	2.34	3.66	4.44	4.55	3.89	4.05	2.84	1.66	1.07	32.09	22.93	71
Racine	100	1.39	1.48	2.52	2.60	3.38	3.16	3.12	2.87	4.08	2.76	2.05	1.49	30.88	19.21	62
Rest Lake	52	1.10	1.02	1.62	2.05	2.97	3.86	4.49	3.57	3.97	2.80	1.84	1.40	30.69	20.91	68
Rhinelander	51	.84	.90	1.55	2.34	3.26	4.28	4.30	3.68	3.68	2.92	1.62	.98	30.35	21.54	71
Shawano	64	1.05	1.08	1.76	2.50	3.30	3.77	4.04	3.00	3.42	2.61	1.80	1.25	29.58	20.03	68
Sheboygan	90	1.62	1.71	2.30	2.53	3.43	3.29	3.01	3.33	3.54	2.72	2.14	1.75	31.38	19.13	61
Solon Springs	67	.98	1.13	1.18	2.12	3.26	4.36	5.04	3.38	3.28	2.64	1.32	1.14	29.83	21.44	72
Spooner	93	.86	.94	1.52	1.90	3.31	4.06	4.31	3.58	3.55	2.39	1.36	.87	28.66	20.71	72
Stanley	77	1.06	1.15	1.79	2.55	4.18	5.01	4.24	3.56	4.30	3.08	1.97	1.10	33.99	23.84	70
Stevens Point	96	1.15	1.18	1.99	2.92	3.80	4.94	3.60	3.69	3.88	2.55	1.84	1.32	32.88	22.83	69
Sturgeon Bay	72	1.32	1.55	2.38	2.97	3.54	3.38	3.46	2.86	3.54	3.02	2.36	1.80	32.18	19.75	61
Superior	63	.57	.53	1.07	1.75	3.30	4.16	3.98	3.17	3.67	2.38	1.23	.71	26.52	20.03	75
Tomahawk	45	1.00	.98	1.96	2.52	3.64	4.14	4.14	3.53	3.54	2.84	1.67	1.06	31.02	21.51	69
Valley Jc.	58	1.13	1.36	2.14	2.78	4.64	4.58	4.30	3.86	4.30	2.84	1.96	1.26	35.15	24.46	70
Viroqua	90	1.04	1.21	1.74	2.72	4.46	4.49	4.50	3.93	4.45	2.71	1.85	1.27	34.37	24.55	71
Watertown	100	1.52	1.49	2.27	2.93	3.93	3.92	3.52	3.42	3.92	2.83	2.12	1.63	33.50	21.64	65
Waukesha	99	1.47	1.35	2.35	2.82	3.77	3.51	3.11	3.28	3.96	2.69	2.02	1.52	31.84	20.45	64
Waupaca	95	1.15	1.25	2.05	2.80	4.06	4.32	3.60	3.65	3.99	2.47	1.99	1.30	32.62	22.42	69
Wausau	99	1.02	1.03	1.82	2.54	3.56	4.03	4.29	3.62	3.85	2.82	1.64	1.16	31.38	21.89	70
Weyerhauser	69	1.10	1.03	1.76	2.28	4.06	4.85	4.60	3.58	4.03	2.90	1.75	1.16	33.10	23.40	71
Whitehall	85	1.07	1.11	1.75	2.31	3.91	4.10	3.74	3.64	4.24	2.41	1.54	1.31	31.14	21.94	70
Williams Bay	96	1.32	1.33	2.24	2.66	3.27	3.50	3.66	3.70	3.58	2.54	1.88	1.57	31.25	20.37	65
Wisconsin Rapids	79	1.10	1.14	1.91	2.72	4.04	4.22	3.78	3.63	4.14	2.61	1.78	1.22	32.29	22.53	70

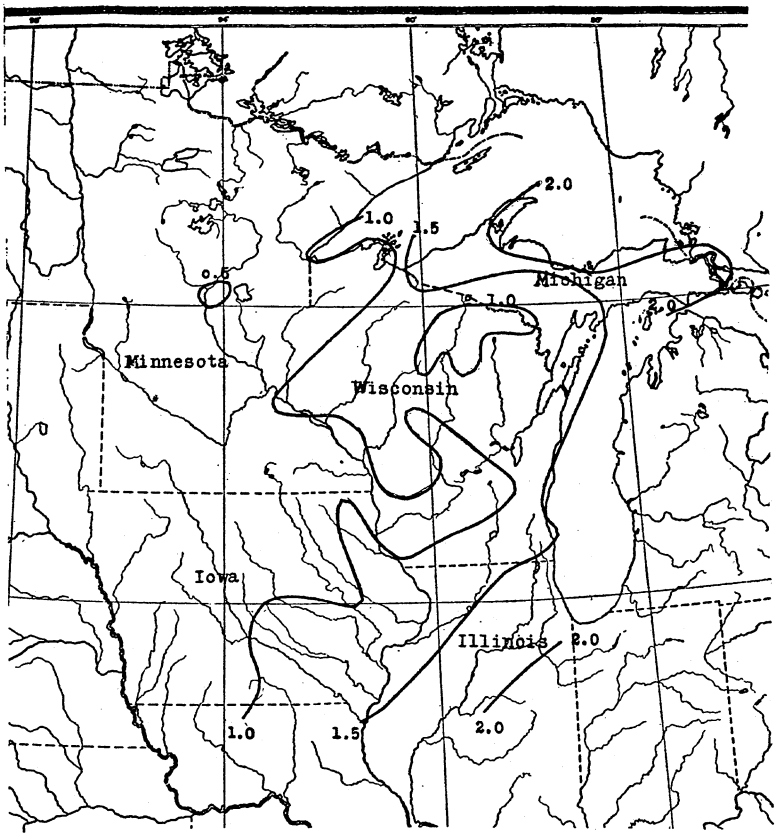

FIG. 1. Average rainfall in Wisconsin and adjoining states. January, 32 years, 1897–1928 inclusive.

Precipitation in January is light, except along the shores of the Great Lakes, and falls mostly in the form of snow. The map shows precipitation increasing southeastward, toward the area of heavy rainfall, averaging 4 to 5 inches, in the lower Mississippi and Ohio valleys. Locally deficient precipitation appears in the northern highlands of Wisconsin and in the lower Wisconsin river valley.

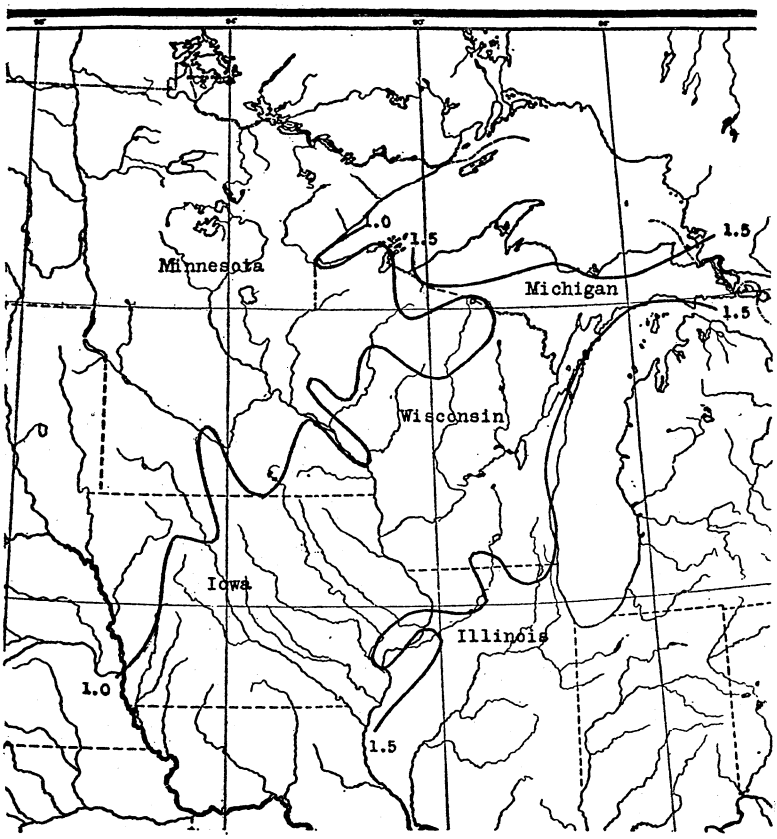

FIG. 2. Average rainfall in Wisconsin and adjoining states. February, 32 years, 1897–1928 inclusive.

The average precipitation does not differ materially from that of January. The snowfall is not quite so heavy along the southern shore of Lake Superior, and the rainfall from the Gulf of Mexico does not reach quite so far northward into Illinois. The ground usually remains snow-covered throughout February.

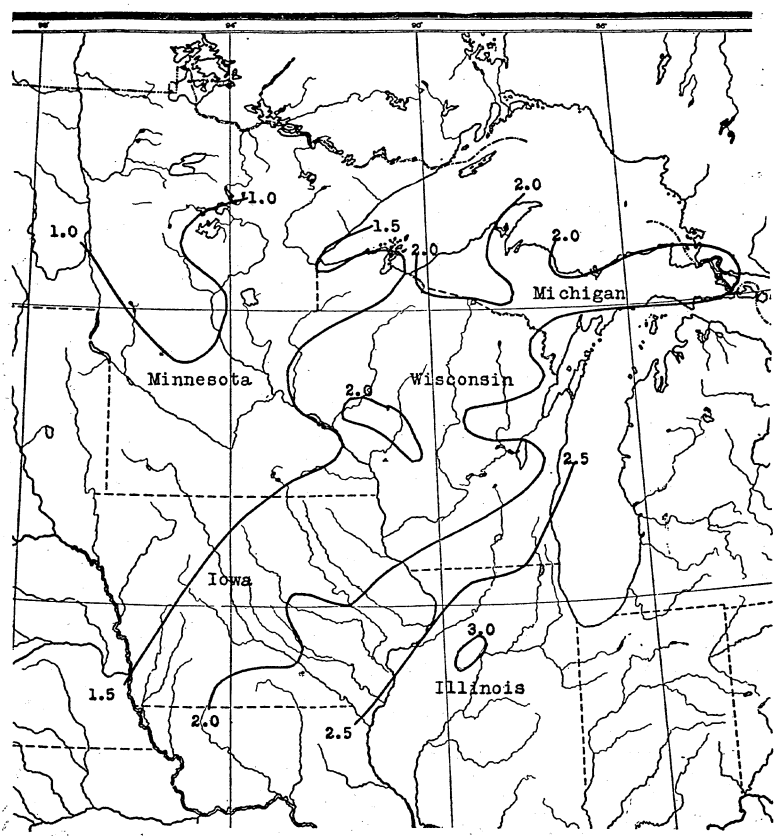

FIG. 3. Average rainfall in Wisconsin and adjoining states. March, 32 years, 1897–1928 inclusive.

The average March precipitation is nearly double that of the preceding month. The snow-cover usually disappears during this month, and rapid warming up begins. Locally heavier rain appears in west central Wisconsin. The precipitation in the form of snow ranges from 5 inches in the southern part of the region, to 10 inches in northern Wisconsin, and to 15 inches in the upper peninsula of Michigan.

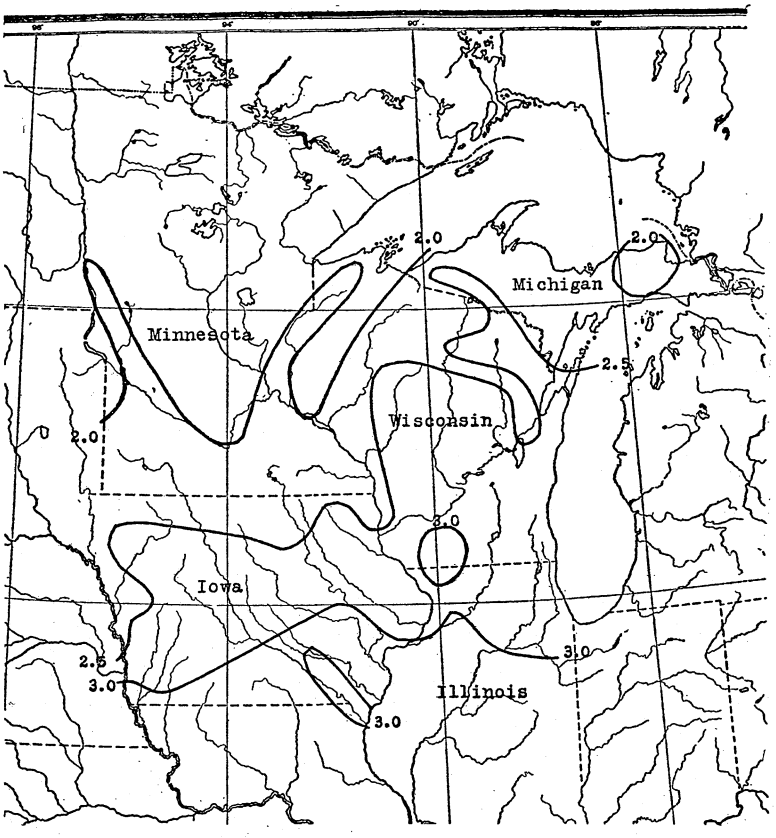

FIG. 4. Average rainfall in Wisconsin and adjoining states. April, 32 years, 1897–1928 inclusive.

As spring advances, a pronounced increase in precipitation takes place. Thunderstorms become more frequent. There is now decidedly heavier precipitation away from the Great Lakes, with a tendency for loops to follow river valleys, e. g., the Wisconsin. St. Croix, and Minnesota river valleys. April and November are the months of greatest frequence of LOWS in the southern part of this region, and these are the cause of the "three-day rains" often spoken of by the inhabitants.

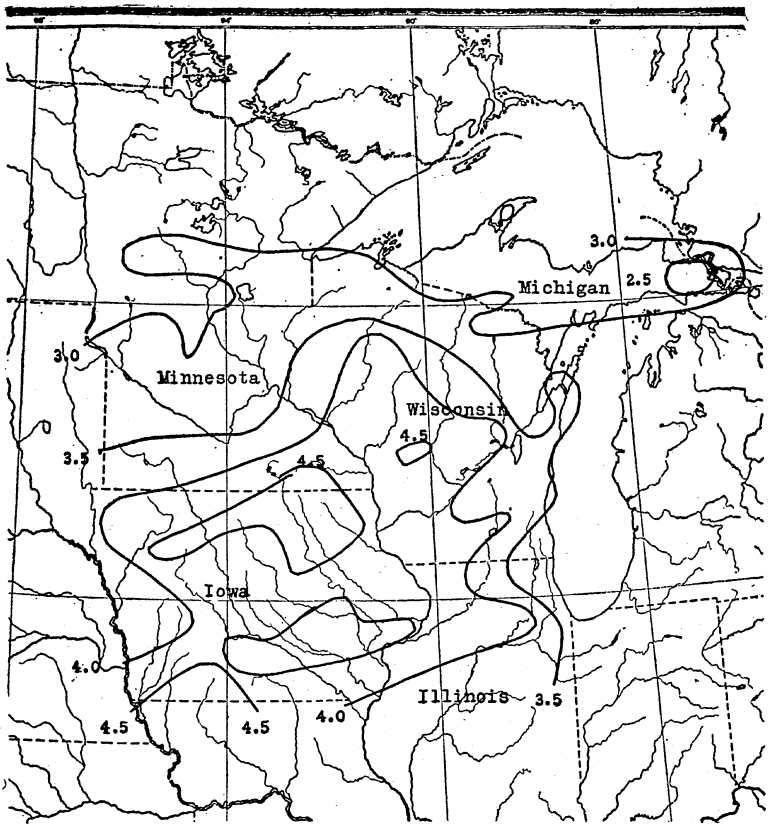

FIG. 5. Average rainfall in Wisconsin and adjoining states. May. 32 years, 1897–1928 inclusive.

The area shown in these maps is at the northern end of a large area of heavy rainfall extending northward from the Gulf of Mexico between the Mississippi valley and the Rocky Mountains. Locally heavier rainfall in west-central Wisconsin, northern, and southwestern Iowa, are associated with rising ground, while regions of less rainfall in the upper Peninsula of Michigan, and southeastern Iowa, under 4 inches, are associated with low or level land. The rainfall along the shore of Lake Michigan has one of its two annual maxima in this month. The other maximum occurs in September.

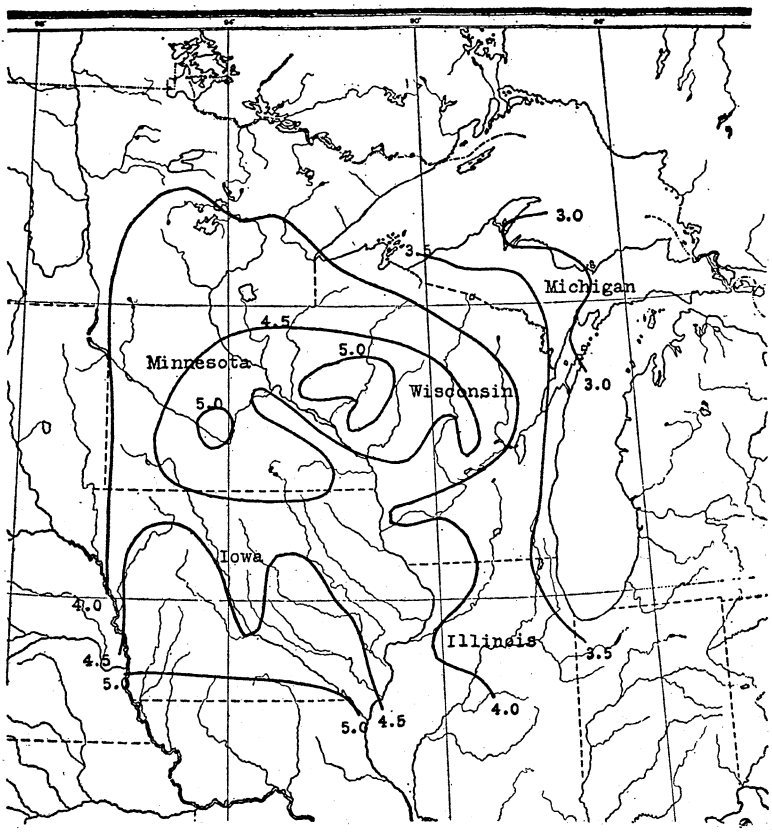

FIG. 6. Average rainfall in Wisconsin and adjoining states. June, 32 years, 1897–1928 inclusive.

The maximum rainfall of the year occurs in this month. The fact that the larger portion of the annual precipitation in this section falls in the spring and summer months gives it prominence as a cereal producing region. The rainfall occurs now mostly in thunderstorms. The Great Lakes are distinctly cooler than the land, and are less favorable to convectional overturning, hence the rainfall is not so great near these large bodies of water.

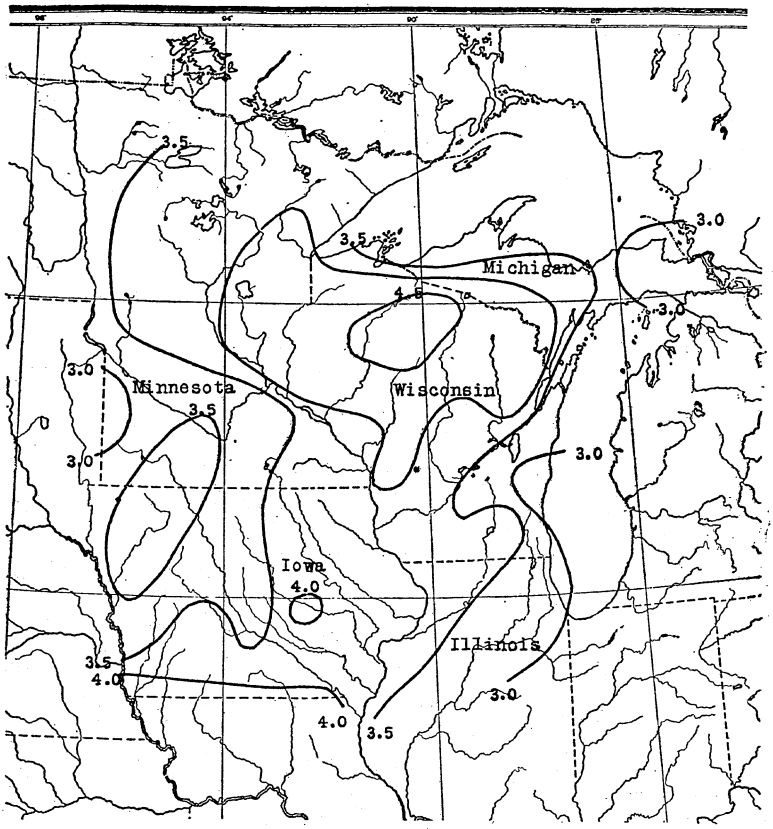

FIG. 7. Average rainfall in Wisconsin and adjoining states. July, 32 years, 1897–1928 inclusive.

July rainfall results largely from local thunderstorms. This is the month of greatest frequence of thunderstorms in the western part of the region shown on these maps. The distribution of rainfall in any one summer may be quite local, leaving areas of drought between well watered areas. The northern highlands of Wisconsin, and the western highlands of Iowa and Minnesota have become warmed up by July, and are the seat of locally heavier rainfall.

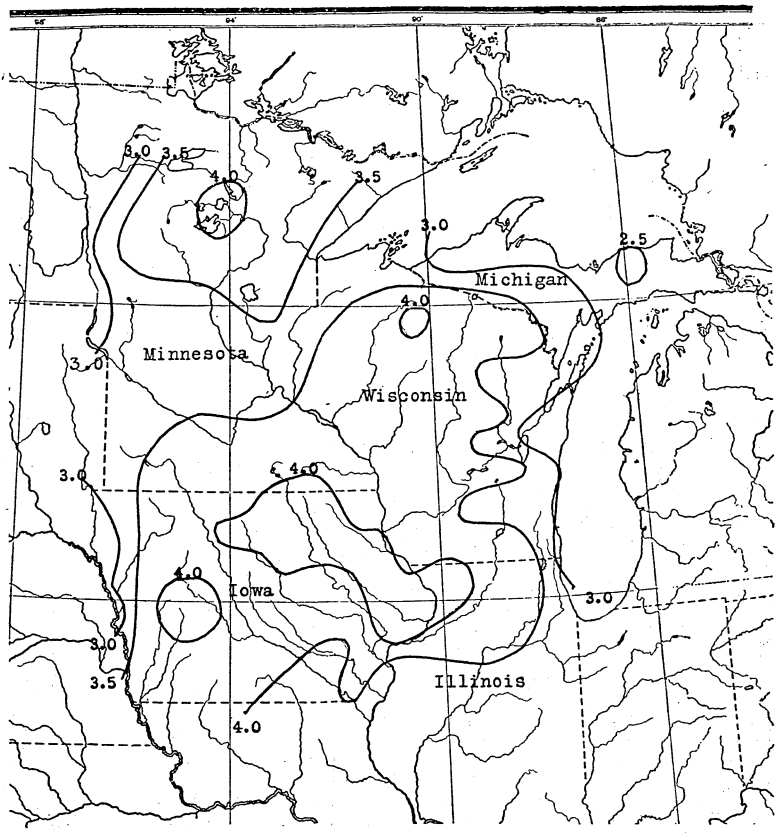

FIG. 8. Average rainfall in Wisconsin and adjoining states. August, 32 years, 1897–1928 inclusive.

In August as in July, rainfall is largely the result of thunderstorms. Although average rainfall is heavy, local droughts are comparatively frequent. This is the month of greatest frequence of LOWS moving along the northern border, and the indraft of hot wind into these often intensifies the injury to vegetation. The northern highlands of Minnesota have become warmed up by August and are the center of an area of locally heavier rainfall.

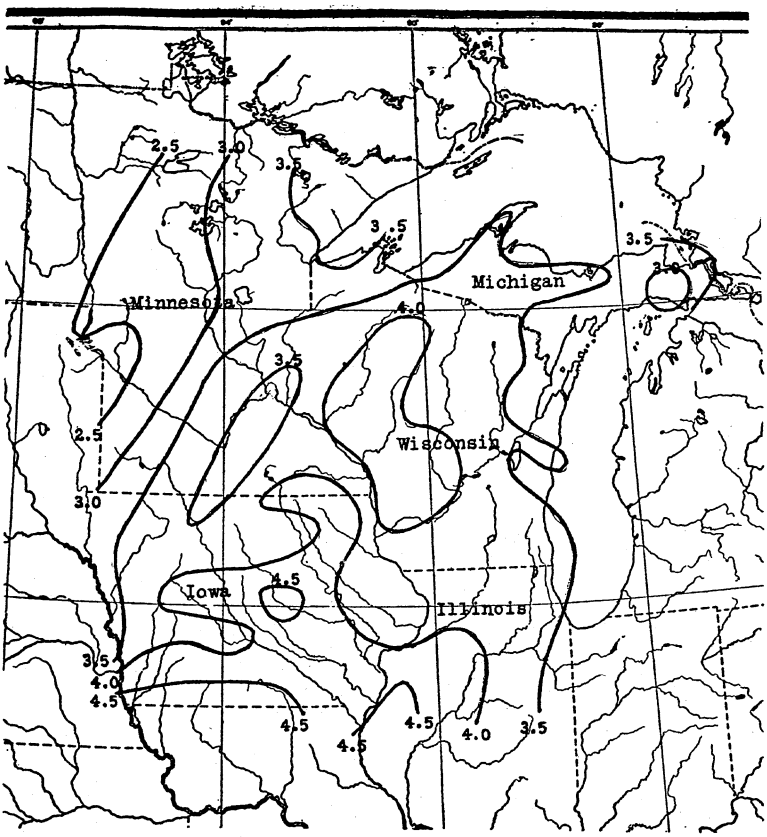

FIG. 9. Average rainfall in Wisconsin and adjoining states. September, 32 years, 1897–1928 inclusive.

The rainfall is appreciably less in the northwestern part of the region, but is greater around the Great Lakes, which are warmer than the land from now until spring. LOWS from the Colorado plateau become more frequent, and with them the 3-day rains begin again.

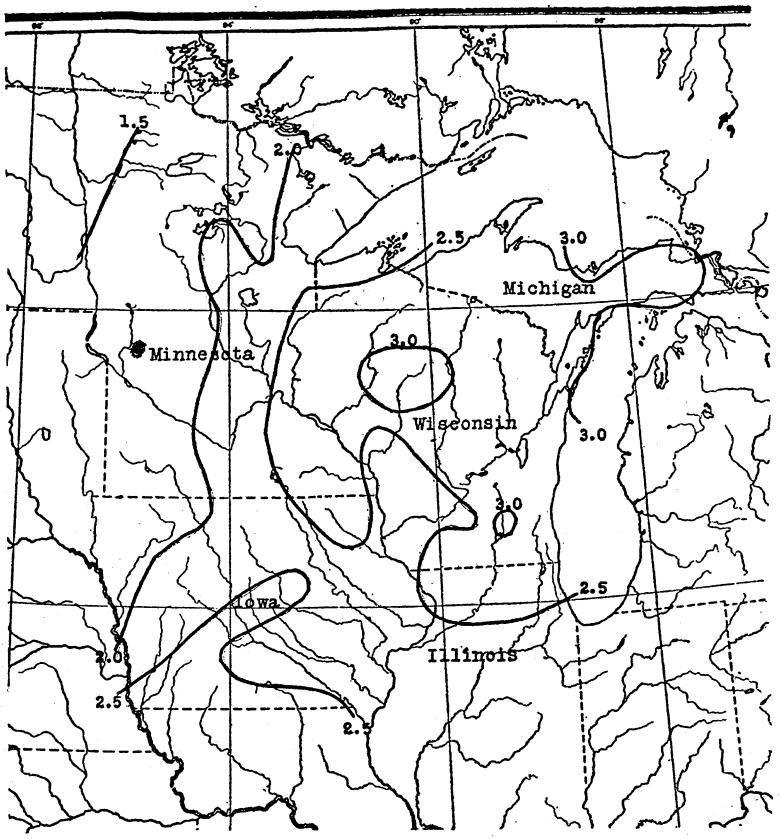

FIG. 10. Average rainfall in Wisconsin and adjoining states. October, 32 years, 1897–1928 inclusive.

The precipitation is considerably less than in September, although the northern highlands of Wisconsin continue to be an area of heavier rainfall. Snow usually falls over the area shown on these maps in October, the average depth being inappreciable, except in northern Wisconsin and around Lake Superior where it averages from 1 to 2 inches.

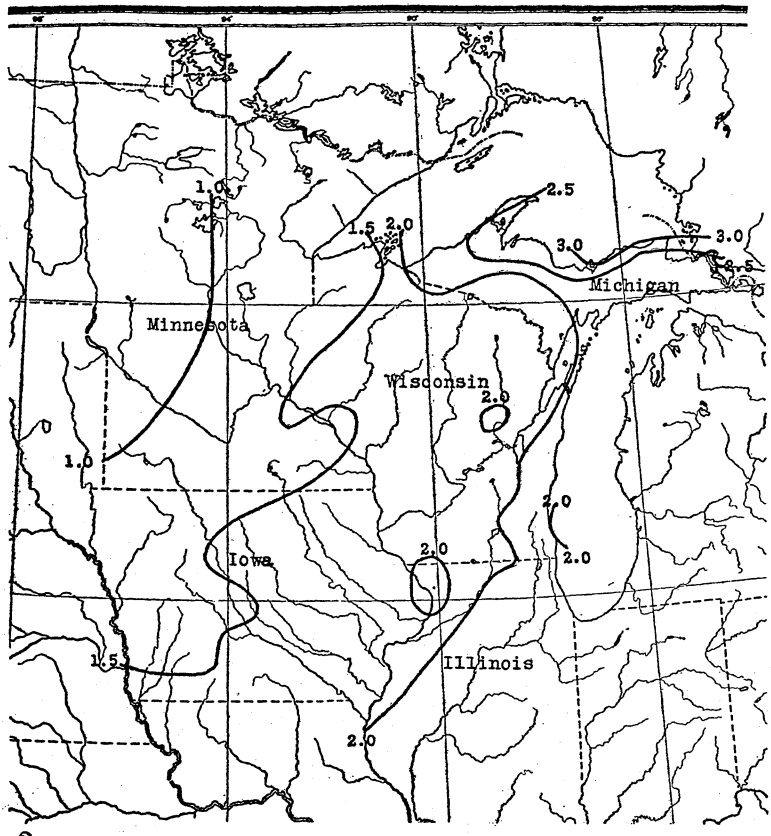

FIG. 11. Average rainfall in Wisconsin and adjoining states. November, 32 years, 1897–1928 inclusive.

The rainfall of November is more uniformly distributed, except in the upper peninsula of Michigan. The average snowfall ranges from 2 inches in the southern part of the area to 15 inches along the northern shore of upper Michigan. The snow does not remain on the ground.

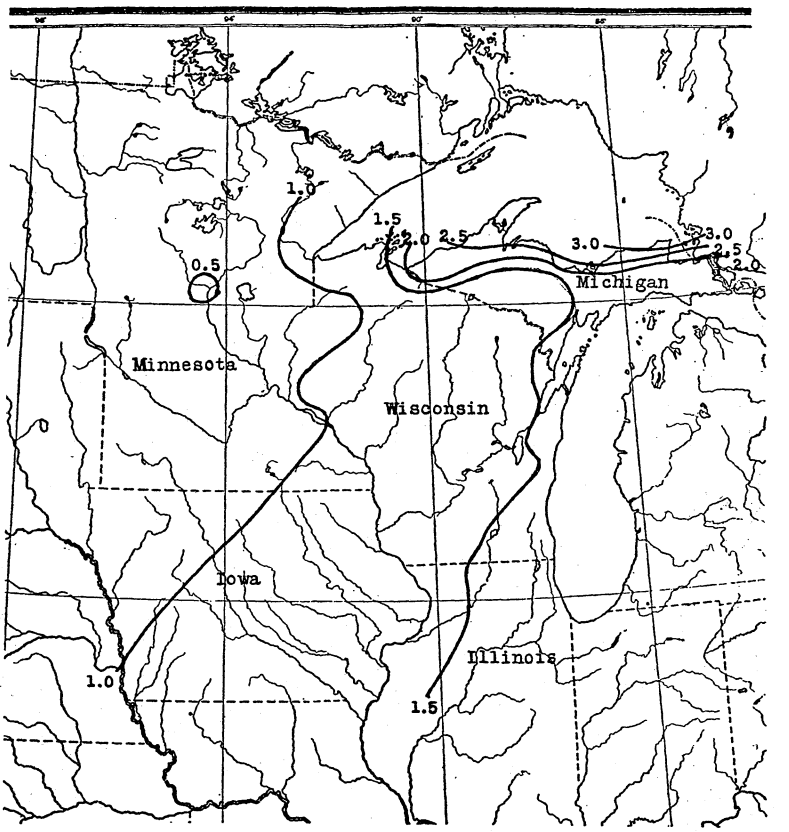

FIG. 12. Average rainfall in Wisconsin and adjoining states. December, 32 years, 1897–1928 inclusive.

Although precipitation is frequent the amount is small, except along the northern shore of the upper peninsula of Michigan, where this month shows totals nearly equal to the maximum in late spring and early summer. The snowfall is about the same as in January, but the snow-cover often fails to extend to the southern part of the section before the end of the month.

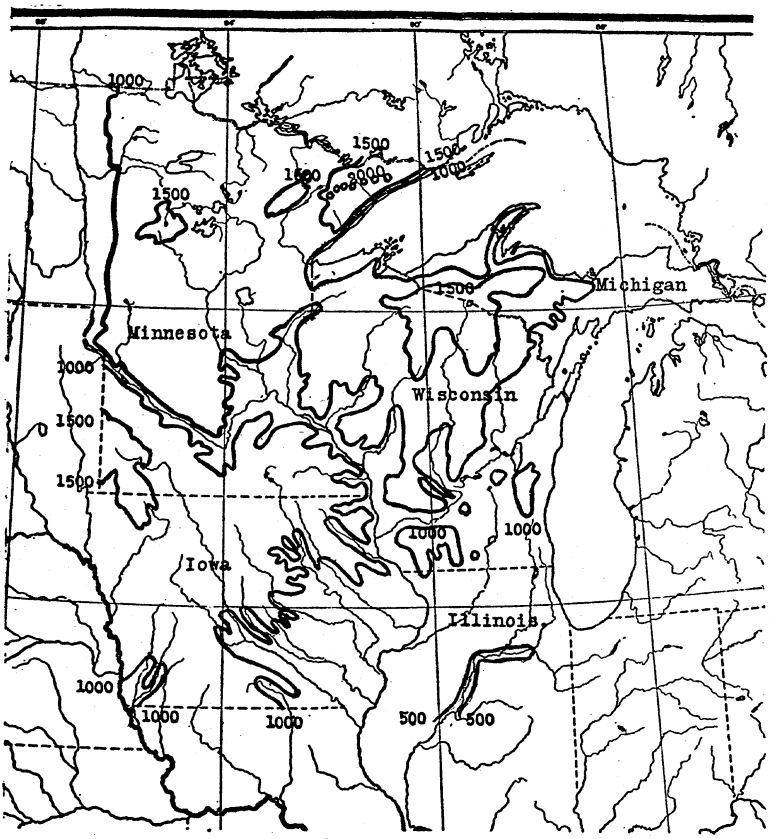

FIG. 13. Topographic map of Wisconsin and adjoining states. Contour interval 500 feet.

THE PLANTS OF SOME NORTHEASTERN WISCONSIN LAKES

NORMAN C. FASSETT

Notes from the Biological Laboratory of the Wisconsin Geological and Natural History Survey and the Department of Botany, University of Wisconsin. XXXVIII.

During a short period in the summer of 1929 (August 26 to September 3) a study was made of the plants of seven lakes in Vilas County and of two in Oneida County, Wisconsin. It was observed that different types of aquatic plants were preponderant in different lakes and that the lakes inhabited by each type had in common certain features of transparency, hydrogen-ion concentration, etc., but no decision was made concerning which, if any, of these factors functioned in determining the growth of each plant type.

The plant types of these lakes may be divided into four groups, as follows: (1) plants with long flexuous stems and compound or flexuous leaves, the whole supported by the water (fig. 1 and table 1); (2) plants with the stiff leaves in a close

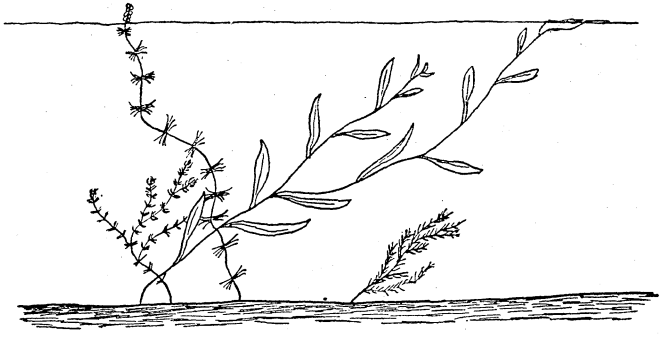

FIG. 1. Plants with long lax stems and compound or flexuous leaves.

rosette or on short, rigid unbranched stems (fig. 2 and table 2); (3) plants with the vegetative stem horizontal and the leaves mostly or entirely floating on the surface of the water (fig. 3 and table 3); and (4) plants with their bases in the water and

photosynthetic parts mostly or entirely emersed (fig. 4 and table 4).

A detailed discussion of each lake follows. In tables 1 to 4 they are arranged in order of hydrogen-ion concentration and fixed carbon dioxide content and may be taken up in this sequence.[1]

FORESTRY BOG. Location, Sect. 8, T. 41 N., R. 7 E. This is a small pool in a Sphagnum bog near the State House, at Trout Lake, Vilas County. The plants surrounding the pool, but usually not actually in the water, are *Sphagnum*[2] spp., *Sarracenia purpurea, Monotropa uniflora, Smilacina trifolia, Chiogenes hispidula, Rynchospora alba, Picea mariana* bearing *Arceuthobium pusillum, Eriophorum virginicum, Larix laricina, Carex oligosperma, C. pauciflora, C. trisperma, Chamaedaphne calyculata, Ledum groenlandicum, Gaultheria procumbens, Vaccinium Oxycoccos, Menyanthes trifoliata, Kalmia polifolia,* and *Andromeda glaucophylla.*

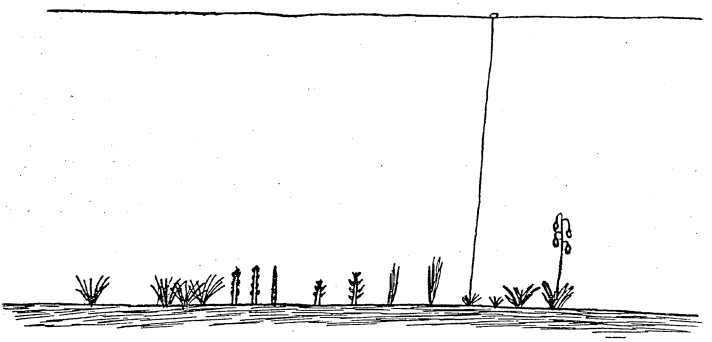

FIG. 2. Plants with stiff leaves in a close rosette or on short, rigid unbranched stems.

It will be observed in the tables that the only member of group 1 occurring in the pool is *Utricularia vulgaris,* var. *americana,* while the only other plants actually in the water are *Nymphozanthus variegatus* (Engelm.) Fernald,[3] *N. microphyllus* (Pers.) Fernald,[3] and *Brasenia Schreberi.*

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[1] For the hydrogen ion concentration and the fixed carbon dioxide results, I am indebted to Dr. E. A. Birge and Mr. C. Juday.

[2] With the exception of *Larix* and the *Sphagnum* species, all of the plants mentioned in this paper are represented by collections in the Herbarium of the University of Wisconsin.

[3] Rhodora **21**: 183–188. 1919. Vascular plants bearing names found in Gray's Manual, ed. 7, are here not followed by authority; others are cited with authority, and a reference accompanies the first mention of each in this paper.

WALKER LAKE. Location, Sect. 15, T. 39 N., R. 7 E. This is also a *Sphagnum*-bordered lake, lying only a few rods from Clear Lake, which is of a surprisingly different nature. Walker Lake is about five miles southeast of Woodruff, in northern Oneida County. While Forestry Bog is in a large sphagnous area, with many species of plants, the boggy margin of Walker Lake appears to be the result of a recent invasion. Here we find *Kalmia polifolia, Andromeda glaucophylla,* and *Calla palustris* spreading over the surface of the water, while *Dulichium arundinaceum* is established on the mucky shore. The only plants in the water are *Nymphozanthus variegatus* (Engelm.) Fernald and *Isoetes Braunii* Dur.[4]

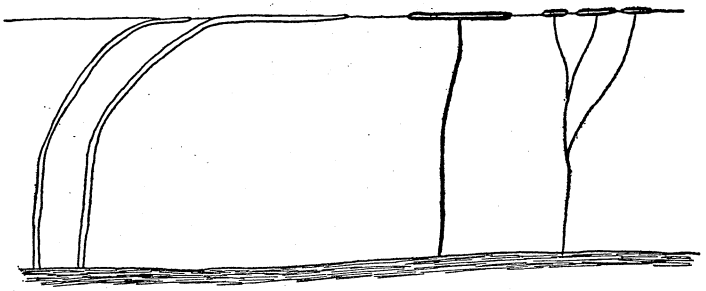

FIG. 3. Plants with the vegetative stem horizontal and the leaves mostly or entirely floating on the surface.

Physical data have not yet been obtained for Walker Lake, but on account of its boggy nature it is placed next to Forestry Bog in the tables.

WEBER LAKE. Location, Sect. 28, T. 41 N., R. 7 E. This lake, and the next two, are characterized by their exceedingly clear water. In Weber Lake a six-inch white disc is visible at 8.0 m.,[5] and in Crystal Lake in 10.7 m., while in the last four lakes in each table the range is only from 2.4 m. to 5.6 m.

Weber Lake is in a sandy pocket in glacial outwash, about five miles southeast of Trout Lake. There is essentially no littoral vegetation, the shrubs and small trees for the most part coming to the water's edge, but at the east end a lagoon behind a low ice rampart are a number of plants not found in the lake itself. The most interesting of these is *Bartonia virginica,*

[4] See Pfeiffer, Ann. Mo. Bot. Gard. **9**: 156. 1922.
[5] Birge & Juday, Bull. Nat. Research Council **68**: 8. 1929 [as Webb Lake].

hitherto known in Wisconsin only on the basis of a very old collection from Marquette County. Other plants of the lagoon are *Gratiola aurea* (an eastern plant little known in Wisconsin), *Habenaria clavellata, Juncus brevicaudatus, J. canadensis, Scirpus atrovirens,* and *S. cyperinus,* var. *pelius.*

The aquatic flora is essentially like that of Crystal Lake, which will be discussed in detail.

CRYSTAL LAKE. Location, Sect. 27 and 28, T. 41 N., R. 7 E. This lake lies a mile east of Weber Lake, which it closely resembles, and a few rods south of Muskellunge Lake, from which

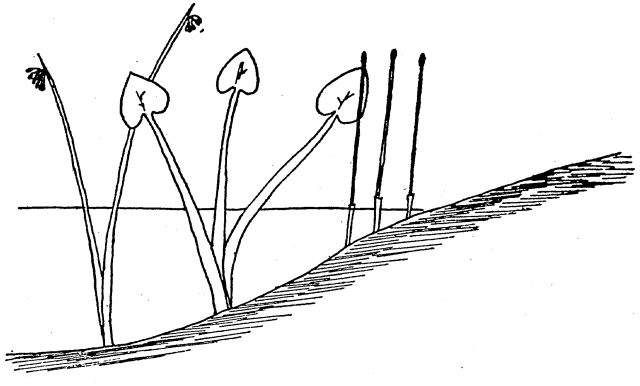

FIG. 4. Plants with their bases in the water and photosynthetic parts mostly or entirely emersed.

it is strikingly different. With pure sand bottom and exceedingly clear water (a 6-inch disc is visible at 8.8–10.7 m.)[6] it presents a remarkable appearance, and its flora is as interesting as its physical nature.

Like Weber Lake, Crystal Lake has essentially no littoral vegetation except for overhanging alders,[7] and like Weber Lake it has a shallow lagoon back of an ice-pushed rampart. Here grow the four species of *Scirpus* and *Juncus* as recorded for Weber Lake, with *Juncus effusus,* a little *Sphagnum,* and *Utricularia intermedia,* all of which are absent from the lake itself.

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[6] Birge & Juday, l. c.

[7] This describes the appearance in August, 1929. I am told that at this time the water was two feet above its level of most years, and that ordinarily there is a narrow sand beach, devoid of vegetation.

As may be seen in table 1, the flexuous-stemmed plants are strictly absent.

The bulk of the vegetation is made up of the rosette-plants and forms with short rigid stems, as listed in table 2:—*Isoetes macrospora, Eleocharis acicularis* (always sterile), *Eriocaulon septangulare* With.[8] (never flowering in Crystal, and but rarely in Weber and Clear Lakes), *Elatine minima* (Nutt.) Fisch. & Meyer,[9] *Myriophyllum tenellum,* and *Lobelia Dortmanna* (occasionally fruiting with the flowers never having emerged).

The submerged forms of two normally terrestrial plants are so different from the typical that they are here described.

Gratiola aurea Muhl., f. **pusilla**, n. f., plantae submersae; caulibus 5–30 mm. altis, simplicibus, 0.75–2 mm. diametro, 10 mm. aut minus inferioribus humatis albisque ferrentibus 1–4 verticillos radicum; paribus foliorum 3–10, extendentiorum, eglandulis, linearibus vel lanceolatis, 4 mm. aut minus longis; floribus fructibusque nullis. Plant submerged; stem 5–30 mm. tall, unbranched, 0.75–2 mm. thick, the lower 10 mm. or less buried, white, bearing 1–4 whorls of roots; leaves in 3–10 pairs, widely spreading, not glandular, linear to lanceolate, 4 mm. or less long; flowers and fruit none.—In water from 1–4 m. deep, Crystal Lake, Vilas County, Wisconsin, August 27, 1929, *Fassett* no. 9090 (TYPE in Herb. U. of Wis.) and 9091; in 1 m. water, Weber Lake, Vilas County, Wisconsin, August 28, 1929, *Fassett* nos. 9092 and 9093.

This is so unlike the terrestrial fertile form that it would hardly have been recognized as a mere submerged phase of *G. aurea* had it not have been for the presence, in 3 dm. of water in Weber Lake, of a single intermediate. This was a little more robust than the deep water form, 3.5 cm. tall and the terminal pairs of leaves had the glands characteristic of this species. Typical *G. aurea,* apparently not at all common in Wisconsin, was found growing very sparingly on the shores of Weber Lake and Trout Lake.

Juncus pelocarpus Mey., f. **submersus**, n. f., plantae sterilae, multis stolonibus; foliis omnibus ad basem, gracilibus, 2–7 cm. longis, septis plerumque sparsis incompletisque, constantius positis completisque ad apicem. Plants sterile, freely stoloniferous; leaves all basal, slender, 2–7 cm. long, the septa mostly scattered and incomplete, more regularly spaced and complete toward the tip.—Common in 1–4 m. water, Crystal Lake, Vilas County, Wisconsin, August 27, 1929, *Fassett* no. 8877 (TYPE in Herb. U. of Wis.); in 5 dm. water, sand bottom, Trout Lake, Vilas County, Wisconsin, August 30, 1929, *Fassett* no. 8881; in 1 m. water, Weber Lake, Vilas County, Wisconsin, August 28, 1929, *Fassett* no. 8872, and in 5 dm. water, no. 8873; in water to 1 m., sparse, Clear Lake, Woodruff, Oneida County, Wisconsin, August 31, 1929, *Fassett* no. 8879.

[8] *E. articulatum* (Huds.) Morong. See Rhodora **11**: 40–41. 1909.
[9] See Fernald, Rhodora **19**: 10–15. 1917.

This deep water form resembles a small stiff sterile *Sagittaria subulata* or *Subularia aquatica.* The typical *Juncus pelocarpus* has septations extending completely across the leaves and regularly spaced, but some specimens show toward the base the irregular incomplete septations which are the rule in f. *submersa.* The terrestrial form, strangely enough, was not found at Crystal or Clear Lakes, and was very rare and with few flowering stems on Weber Lake. It was almost equally rare on Trout Lake, where the submerged form occurred sparingly.

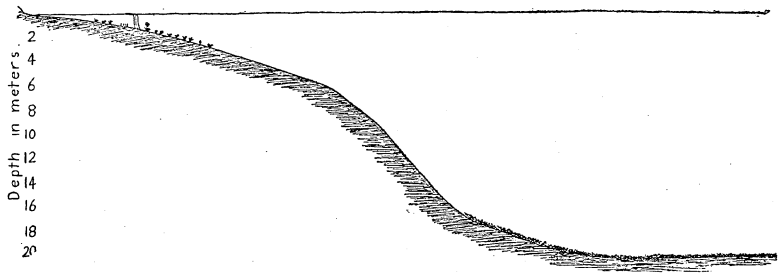

FIG. 5. Distribution of plants in Crystal Lake.

Of the plants with floating leaves (table 3) only *Sparganium angustifolium* is present, in one small patch, not flowering, in Crystal Lake, and very localized and rarely flowering in Weber and Clear Lakes. While the hydrogen-ion concentration may be the factor limiting the distribution of the *Potamogeton* species, *Elodea canadensis,*[10] *Ceratophyllum, Vallisneria,* etc., this can hardly be the case with the two species of *Nymphozanthus,* which are in lakes both more and less acid than the three clear-water lakes, or the *Brasenia,* found in the most acid and most alkaline lakes here considered.

We might expect that, due to the low fixed carbon dioxide content of the clear-water lakes, plants with emersed photosynthetic parts (table 4) might be more abundant, but the reverse is true. These plants are absent.

Equally as strange as the limitation of the types of plants is the distribution of these plants in Crystal Lake, as indicated in fig. 5. Since this small body of water was explored in some detail by the writer, he is prepared to say that the diagram represents conditions along almost any radius. The gentle slope from the shore to a depth of six meters is populated for only about two-thirds of its distance. This is not a matter of light deficiency, for one may clearly see from a boat the unpopulated

[10] See St. John, Rhodora **22**: 27. 1920.

area of unbroken bare sand with a very thin, slightly irregular layer of decayed material. This bare condition persists to a depth of about fifteen meters, where the mosses *Fontinalis flaccida* and *Drepanocladus fluitans, var. submersus, f. filiformis*[11] occur. They cover the bottom even in the deepest water (twenty meters) where only 1–4% of the solar radiation penetrates,[12] and are brought up in great masses by the dredge. The only collections of this moss outside of the deepest water of Crystal and Weber Lakes was a nearly terrestrial form of the *Drepanocladus* in the lagoon of the latter. No dredge hauls were made in Clear Lake.

CLEAR LAKE. Location, Sections 9, 10, & 15, T. 39 N., R. 7 E. This is about five miles southeast of Woodruff, in northern Oneida County, and is very close to the Sphagnum-bordered Walker Lake. The only species these two lakes have in common, however, is *Dulichium arundinaceum,* on the sandy shore of the former, and the mucky shore of the latter, but hardly venturing actually into the lakes. The flora of Clear Lake is essentially the same as that of Crystal Lake and of Weber Lake, but much more sparse than in either of these.

MUSKELLUNGE LAKE. Location, Sections 27 & 28, T. 41 N., R. 7 E. Lying close to Crystal Lake, this body of water differs from it in pH, being about neutral, in fixed carbon dioxide content, and in transparency a 6-inch white disc being visible at but 4.2 m.[13] The only part of this lake studied was the bay at the south end; here, instead of the clean sand bottom of Crystal Lake, is a muck bottom, with occasional stony places. Whether these physical differences are the cause or the result of the striking differences in the plants is a question which will admit of some speculation. Neither lake has an outlet at present, but I am informed by Mr. C. Juday that Muskellunge had an outlet before the lowering of its level due to the cutting of the forest. Each lake is about twenty meters deep, but the deeper parts of Muskellunge were not investigated by the writer.

Muskellunge Lake, at least at the south end where visited by the writer, has very little shore vegetation. But in the water

[11] For determination of these mosses I am indebted to Mr. R. S. Williams of the New York Botanical Garden and to Mr. L. S. Cheney of Barron, Wisconsin. Mr. Williams writes concerning the *Drepanocladus,* "The deepest record we had for this last before was 35 ft., specimens from Oregon."

[12] Readings made in the summer of 1929 by Birge and Juday.

[13] Birge & Juday, l. c.

is a veritable aquatic jungle (fig. 6). The flexuous-stemmed plants listed in table 1 are exceedingly abundant, as are the types with floating leaves listed in table 2. The short-stemmed and rosette forms of table 2, while representing several species, are rare and localized. And while *Sagittaria graminea,*

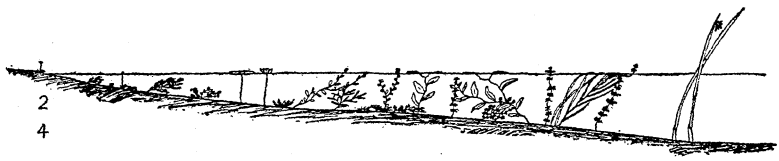

FIG. 6. Distribution of plants in Muskellunge Lake.

as found in Clear Lake, is strictly of the rosetted phylodial form, *S. cuneata* Sheldon[14] in Muskellunge Lake (new to northern Wisconsin[15]) produces long-petioled leaves with floating hastate blades as well as the phyllodial type, and so should perhaps be classified in table 3.

TROUT LAKE. Locations of regions studied, Sections 6 & 8, T. 41 N., R. 7 E. Three points on this lake were investigated, so the list is more complete than for Muskellunge, Wolf, and Wildcat Lakes (the others are so small that probably few species were overlooked). The shallow water off the sand beach at State House was dredged for plants; collections were made in a small bay on the west side of the lake, just above the Narrows; and several forms were taken on the shore and in the shallow water off the sandy beach a mile north of the Narrows, again on the west side.

The writer was impressed, on seeing Trout Lake, with the lack of littoral plants, as compared with the lakes of northwestern Wisconsin. The relic lakes[16] in the barrens region from Bayfield County southwestward to St. Croix Falls have sandy shores densely populated by strand plants whose seeds are obviously water-carried, as evidenced by the occurrence of the annual species in the lines of litter left by the different wave advances. The sandy beach in front of the State House appears essentially like that of the more western lakes, but the only plants are *Agrostis hyemalis, Muhlenbergia umbrosa*

[14] *S. arifolia* Nutt. For synonymy, see Britton & Brown, Ill. Fl. ed. 2, **1**: 99. 1913, or Fassett, Wis. Acad. Sci., Arts & Let. **24**: 250. 1929.

[15] See Fassett, l. c., p. 252, fig. 8.

[16] See Aldrich & Fassett, Science **70**: 45–46. 1929.

Scribn., var. *attenuata* (Scribn.) Deam.,[17] *Scutellaria epilobifolia* Hamilton,[18] *Mentha arvensis,* var. *glabrata, Lycopus uniflorus,* and *Solidago graminifolia.* A flora more characteristically lacustrine was found on the sandy beach a mile above the Narrows; here was a sparse growth of *Sagittaria latifolia,* f. *hastata, Ranunculus reptans* L., var. *ovalis* (Bigel.) T. & G.,[19] *Juncus pelocarpus, Eleocharis olivacea* (new to Wisconsin), *Carex gynandra* Schwein,[19] *C. cryptolepis* Mackenzie,[20] *C. comosa, Cicuta bulbifera, Campanula aparinoides* (new to north-central Wisconsin[21]), *Bidens cernua,* and *Gratiola aurea.* In spite of the presence of the last, *G. aurea, f. pusilla* was not found and the plants of table 2 were decidedly rare as compared with those of table 1.

WOLF LAKE. Location of part studied, Sect. 6, T. 42 N., R. 7 E. Lying about three miles north of Boulder Junction, this lake was not thoroughly explored by the writer. A heavy wind made any viewing of the bottom impossible and the list of plants is probably very incomplete.

WILDCAT LAKE. Location of part studied, Sect. 34, T. 43 N., R. 7 E. This lake is five miles north of Boulder Junction, and is the most alkaline of those studied. In spite of this alkalinity, some of the bays have sphagnous shores, with typical bog plants. The situation, apparently, is very similar to that recently described for Mud Lake, Sheboygan County, Michigan.[22] On one of these bogs was found a copious growth of *Bidens connata,* var. *ambiversa* Fassett,[23] which must be rare in Wisconsin, for the writer had been unable to find it since its publication.

Basal rosettes of *Sagittaria graminea,* in a large form simulating *S. cuneata,* were found to be locally abundant; otherwise plants of table 2 were not seen in Wildcat Lake. The others are well represented, both in number of species and in quantities of each species present.

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[17] Grasses of Ind. (Dept. of Conservation Publication **82**) 171. 1929.
[18] *S. galericulata* Auct. Am., not L. See Fernald, Rhodora **23**: 85–86. 1921.
[19] *R. Flammula,* var. *reptans.* See Fernald, Rhodora **19**: 137. 1917.
[19] See Mackenzie in Britton & Brown, Ill. Fl. ed. 2, **1**: 425. 1913.
[20] Torreya **14**: 157. 1914.
[21] See Mahony, Trans. Wis. Acad. Sci., Arts & Let. **24**: 360, fig. 11. 1929.
[22] Ecology **10**: 465. 1929.
[23] Rhodora **30**: 33. 1928.

TABLE 1. *Plants with long lax stems and compound or flexuous leaves*

	Bog Lakes		Clear-water lakes						
	Forestry Bog pH 4.8—5.6 fixed CO_2 0.8-3.0 p.p.m.	Walker Lake	Weber Lake pH 5.8–6.7 fixed CO_2 0.9-1.8 p.p.m.	Crystal Lake pH 5.9–6.7 fixed CO_2 1.3-2.8 p.p.m.	Clear Lake pH 6.6–6.8 fixed CO_2 1.8-3.5 p.p.m.	Muskellunge Lake pH 6.8–8.2 fixed CO_2 9.0-10.5 p.p.m.	Trout Lake pH 7.3–82 fixed CO_2 17.8—20.0 p.p.m.	Wolf Lake pH 7.5–9.0 fixed CO_2 20.6-26.9 p.p.m.	Wildcat Lake pH 7.6–8.4 fixed CO_2 26.8–33.5 p.p.m.
Potamogeton natans						X		X	X
P. amplifolius							X		
P. epihydrus							X		
P. gramineus L., var. graminifolius Fries[1]						X	X		X
P. gramineus var spathaeformis Robbins[2]							X		
P. praelongus									X
P. Richardsonii							X		X
P. pusillus							X		
P. dimorphus							X		
P. Robbinsii						X	X		
P. pectinatus								X	X
P. filiformis Pers., var. borealis (Raf.) St. John[3]							X		
Najas flexilis							X	X	X
Elodea canadensis[4]							X	X	
Ceratophyllum demersum							X		X
Myriophyllum sp.[5]							X	X	
M. alternifolium						X			X
Utricularia vulgaris, var. americana	X								
Bidens Beckii						X			X

[1] *P. heterophyllus* Am. Auth., not Schreb. See Fernald, Rhodora **23**: 189. 1921.
[2] *P. spathaeformis* Tuckerm. See Fernald, l. c., p. 190.
[3] Rhodora **18**: 134. 1916.
[4] *Sensu* St. John, Rhodora **22**: 27. 1920.
[5] Probably *M. verticillatum.*

TABLE 2. *Plants with stiff leaves in a close rosette or on short, rigid unbranched stems*

	Bog lakes		Clear-warer lakes						
	Forestry Bog pH 4.8—5.6 fixed CO_2 0.8-3.0 p.p.m.	Walker Lake	Weber Lake pH 5.8–6.7 fixed CO_2 0.9-1.8 p.p.m.	Crystal Lake pH 5.9–6.7 fixed CO_2 1.3-2.8 p.p.m.	Clear Lake pH 6.6–6.8 fixed CO_2 1.8-3.5 p.p.m.	Muskellunge Lake pH 6.8–8.2 fixed CO_2 9.0-10.5 p.p.m.	Trout Lake pH 7.3–82 fixed CO_2 17.8—20.0 p.p.m.	Wolf Lake pH 7.5–9.0 fixed CO_2 20.6–26.9 p.p.m.	Wildcat Lake pH7. 6–8.4 fixed CO_2 26.8–33.5 p.p.m.
Isoetes macrospora		X	X	X	X	X	X		
1. Braunii Dur.		X							
Sagittaria cuneata Sheldon						X			
S. graminea					X				
Eleocharis acicularis				X			X		
Eriocaulon septangulare With.			X	X	X	X			
Juncus pelocarpus f. submersus Fassett			X	X	X		X		
Ranunculus reptans L., var. ovalis (Bigel.) T. & G.					X				
Elatine minima (Nutt.) Fisch. & Mey.			X	X	X	X			
Myriophyllum tenellum			X	X		X	X		
Gratiola aurea, f. pusilla Fassett			X	X	X				
Lobelia Dortmanna			X	X	X	X	X		

TABLE 3. *Plants with the vegetative stem horizontal and the leaves mostly or entirely floating on the surface of the water*

	Bog lakes		Clear-water lakes						
	Forestry Bog pH 4.8—5.6 fixed CO_2 0.8-3.0 p.p.m.	Walker Lake	Weber Lake pH 5.8–6.7 fixed CO_2 0.9-1.8 p.p.m.	Crystal Lake pH 5.9–6.7 fixed CO_2 1.3-2.8 p.p.m.	Clear Lake pH 6.6–6.8 fixed CO_2 1.8-3.5 p.p.m.	Muskellunge Lake pH 6.8–8.2 fixed CO_2 9.0-10.5p .p.m.	Trout Lake pH 7.3–82 fixed CO_2 17.8—20.0 p.p.m.	Wolf Lake pH 7.5–9.0 fixed CO_2 20.6–26.9 p.p.m.	Wildcat Lake pH7. 6–8.4 fixed CO_2 26.8–33.5 p.p.m.
Sparganium angustifolium			X	X	X	X			
S. fluctuans						X			X
Vallisneria americana Michx[1]							X	X	X
Polygonum natans A. Eaton, f. genuinum Stanford[1]						X			
Nymphozanthus variegatus (Engelm.) Fernald	X	X				X		X	X
N. microphyllus (Pers.) Fernald	X					X			
Castalia odorata						X		X	X
Brasenia Schreberi	X								X

[1] *V. spiralis* Am. Auth., not L. See Rhodora **20**: 108. 1918.
[2] *P. amphibium* Am. Auth., not L. See Rhodora **27**: 158. 1925.

TABLE 4. *Plants with bases in the water and photosynthetic parts mostly or entirely emersed*

	Bog lakes		Clear-water lakes						
	Forestry Bog pH 4.8—5.6 fixed CO_2 0.8-3.0 p.p.m.	Walker Lake	Weber Lake pH 5.8–6.7 fixed CO_2 0.9-1.8 p.p.m.	Crystal Lake pH 5.9–6.7 fixed CO_2 1.3-2.8 p.p.m.	Clear Lake pH 6.6–6.8 fixed CO_2 1.8-3.5 p.p.m.	Muskellunge Lake pH 6.8–8.2 fixed CO_2 9.0-10.5 p.p.m.	Trout Lake pH 7.3–82 fixed CO_2 17.8—20.0 p.p.m.	Wolf Lake pH 7.5–9.0 fixed CO_2 20.6–26.9 p.p.m.	Wildcat Lake pH 7.6–8.4 fixed CO_2 26.8–33.5 p.p.m.
Equisetum limosum L.[1]	------	------	------	------	------	------	------	X	------
Eleocharis palustris, var. major	------	------	------	------	------	------	X	------	------
Scirpus acutus Muhl[2]	------	------	------	------	------	X	X	------	X
Pontederia cordata	------	------	------	------	------	------	------	------	X
Decodon verticillatus, var. laevigatus T. & G.[3]	------	------	------	------	------	------	------	X	------

[1] *E. fluviatile* L. See Rhodora **23**: 43–47. 1921.
[2] *S. occidentalis* (Wats.) Chase. See Rhodora **22**: 55. 1920.
[3] See Rhodora **19**: 154–155. 1917.

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. IV

LYCOPODIACEAE, SELAGINELLACEAE

LEONARD R. WILSON

The maps compiled for this report of the Lycopodiums and Selaginellas of Wisconsin are from specimens in the herbaria of the University of Wisconsin, of the Milwaukee Public Museum, of Mrs. J. H. Somerville, Superior, Wis., of Iowa State College, and of L. R. Wilson, Superior, Wis.

KEY TO THE LYCOPODIUMS OF WISCONSIN

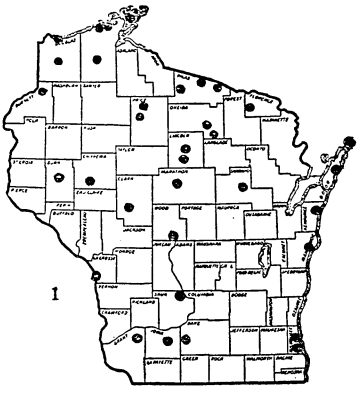
A. Sporophylls not different from foliage leaves
- *B.* Leaves broadest above middle, distinctly serrate; stems procumbent ---------- *L. lucidulum*
- *B.* Leaves linear, or lance-attennate, entire or slightly serrate; stems erect ---------- *L. lucidulum*, var. *porophilum*

A. Sporophylls different from foliage leaves
- *C.* Sporophylls somewhat herbaceous ---------- *L. inundatum*
- *C.* Sporophylls scale-like
  - *D.* Strobile sessile
    - *E.* Plant tree-like; rootstock deep
      - *F.* General shape of plant oblong-ovate; leaves about 1 mm. broad, spreading *L. obscurum*
      - *F.* General shape of plant flabelliform; leaves less than 1 mm. broad, incurved *L. obscurum*, var. *dendroideum*
    - *E.* Plant not tree-like; rootstock superficial
      - *G.* Leaves spreading
        - *H.* Leaves lanceolate to oblanceolate, distinctly serrate, thin ---------- *L. annotinum*
        - *H.* Leaves linear, or lance-attenuate, entire, or slightly serrate, thickish *L. annotinum*, var. *acrifolium*
      - *G.* Leaves appressed, linear, or lance-attenuate, entire, thick ---------- *L. annotinum*, var. *pungens*

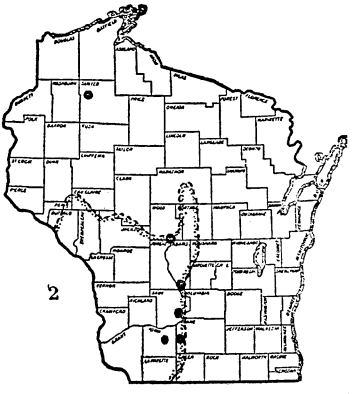
D. Strobile peduncled
I. Leaves linear-awl-shaped
J. Strobiles more than one
K. Strobiles two
L. Strobiles sessile on peduncle ---- *L. clavatum*
L. Strobiles on short secondary peduncles ---------- *L. clavatum*, var. *laurentianum*
K. Strobiles three or more ---------- *L. clavatum*, var. *subremotum*
J. Strobile one; peduncle 3–9 cm. long---- *L. clavatum*, var. *megastachyon*
I. Leaves scale-like
M. Branches with constrictions
N. Branches 1–1.5 mm. wide, rather squarish; ventral median leaf reaching, or overlapping, the leaf above; plant glaucous ---------- *L. tristachyum*
N. Branches 1–3 mm. wide, flattened; ventral median leaves much shortened, on the older branches each not reaching the one above
O. Rootstock superficial; strobiles sessile on peduncle ---------- *L. complanatum*
O. Rootstock deep; strobiles on short secondary peduncles; branches spreading --------- *L. complanatum*, var. *elongatum*
M. Branches without constrictions, fan-shaped, 1–3.5 mm. wide; ventral median leaves much reduced ---------- *L. flabelliforme*

LYCOPODIUM LUCIDULUM Michx. (Fig. 1.) This is the most widely distributed species occurring in Wisconsin. Its occurrence is largely northern, but it is found not infrequently in rich woods of the southern counties, where it was probably much more abundant before the forests were cut.

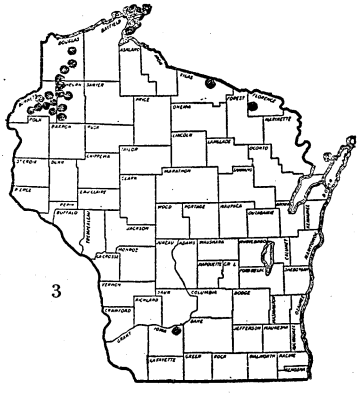
L. LUCIDULUM, var. POROPHILUM (L. and U.) Clute. (Fig. 2.) With one exception var. *porophilum* is known in this state from only the unglaciated region and its border. The typical habitat is upon sandstone cliffs, cold canyons, and exposed places, such as one finds in the Dells of the Wisconsin River. The exception to this range is a specimen collected by R. H. Denniston on August 16, 1916, near Hayward, Sawyer County. The specimen is intermediate between the type and the variety. The sandy conditions near Hayward may be such as to produce



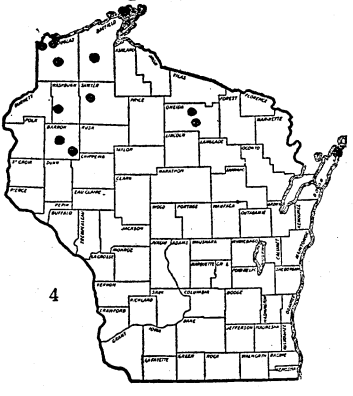
L. lucidulum



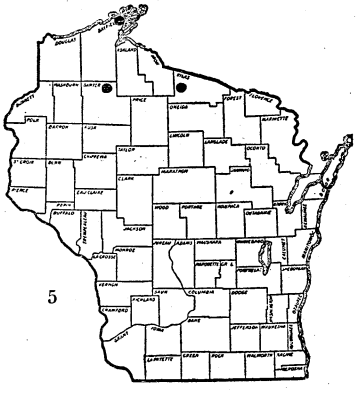
L. lucidulum var. porophilum



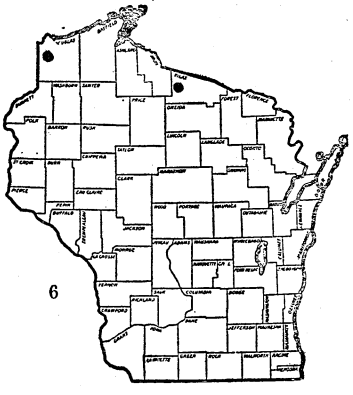
L. inundatum.



L. annotinum



L. annotinum var. acrifolium



L. annotinum var. pungens.

this form, but more study is necessary to account for such a unique distribution. Fig. 2 also shows the unglaciated region.

L. INUNDATUM L. (Fig. 3). Generally restricted to the sandy lake shores of the northern counties, with the exception of one collection near Arena, Iowa County, by J. J. Davis on Sept. 1, 1922. The work with this species by W. T. McLaughlin in Burnett and Washburn Counties, during the summer of 1929, shows the results of intensive collecting, such as is necessary in all of the state to reveal the history of the Wisconsin vegetation. (See Aldrich & Fassett, Botanical and Geological Evidence for an Ancient Lake. Science 70: 1802. 1929.)

L. ANNOTINUM L.; Fernald, Rhodora 17: 124. 1915. (Fig. 4). Northern; growing generally in rocky soil. Fernald has recognized three varieties, two of which have been found in Wisconsin.

L. ANNOTINUM, var. ACRIFOLIUM Fernald, l. c. (Fig. 5). Strictly northern, and probably limited to cold woods and edges of Sphagnum bogs.

L. ANNOTINUM, var. PUNGENS Desv.; Fernald, l. c. (Fig. 6). Strictly northern and confined generally to the edges and higher parts of Sphagnum bogs.

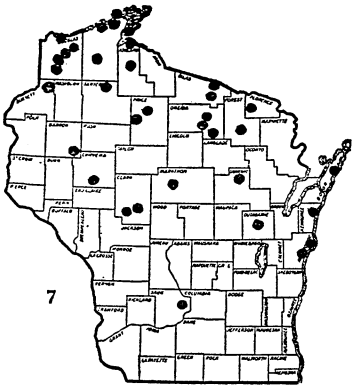
L. OBSCURUM L.; Fernald, Rhodora 23: 272. 1921. (Fig. 7). Northern. More common than the variety, for which most material is mistaken, but the coarseness and spreading character of the leaves in the type, contrasted with the fineness and incurved character of the leaves in the variety, at once distinguishes the two.

L. OBSCURUM, var. DENDROIDEUM (Michx.) D. C. Eaton.; Fernald, l. c. (Fig. 8). Generally northern. The habitat is apparently sandy soil, which is drier than that in which the type is found.

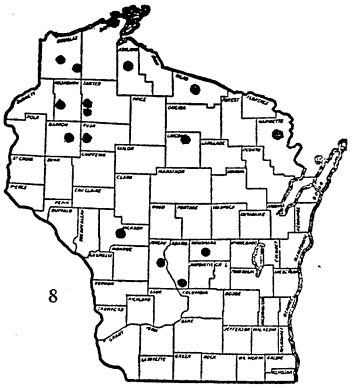
L. CLAVATUM L.; Victorin, Contrib. du Lab. de Bot. de l'Univ. de Montréal. No. 3: 102. 1925. (Fig. 9). More common in the northern counties, and found generally in rocky woods. Three varieties have been recognized by Victorin.

L. CLAVATUM, var. LAURENTIANUM Victorin, l. c., 23. (Fig. 10). Known only from the northern part of the state.

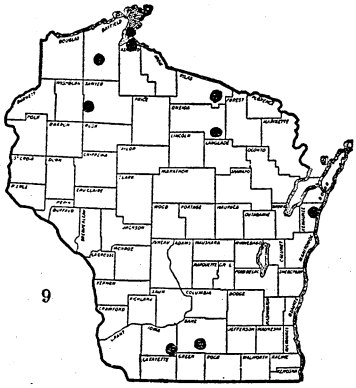
L. CLAVATUM, var. SUBREMOTUM Victorin, l. c., 24. (Fig. 11). Collected several times at Solon Springs, Douglas County.



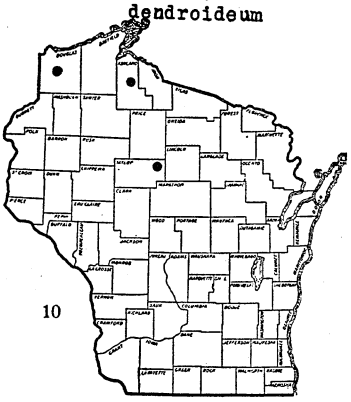
L. obscurum



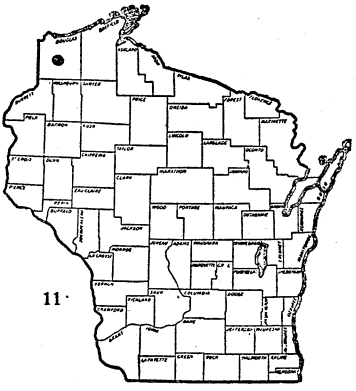
L. obscurum var. dendroideum



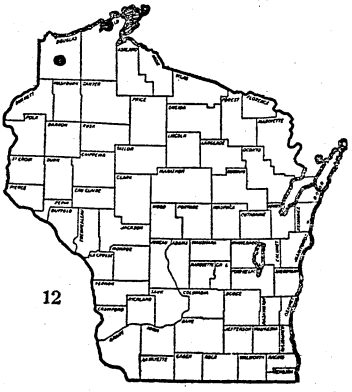
L. clavatum



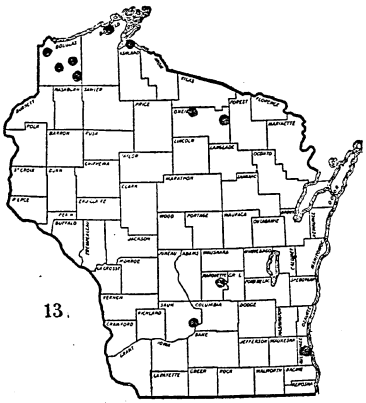
L. clavatum var. laurentianum



L. clavatum var. subremotum

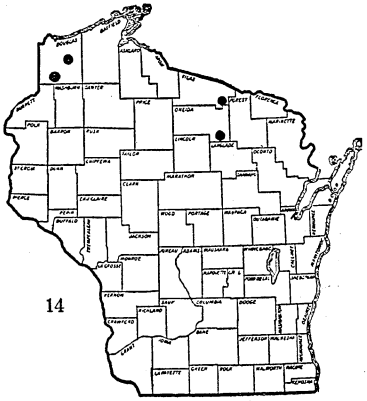


L. clavatum var. megastachyon



13.

L. tristachyum



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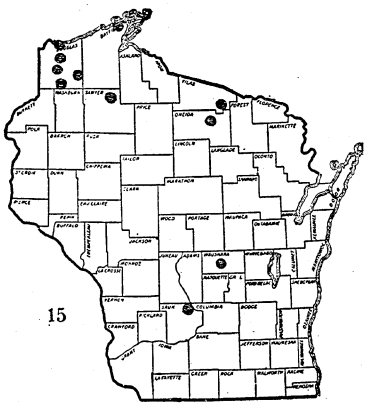
L. complanatum



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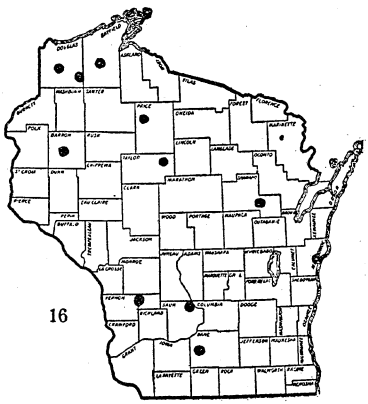
L. complanatum var. elongatum



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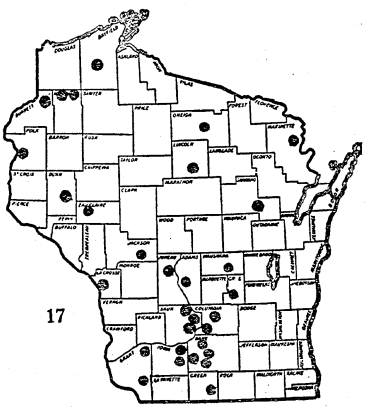
L. flabelliforme



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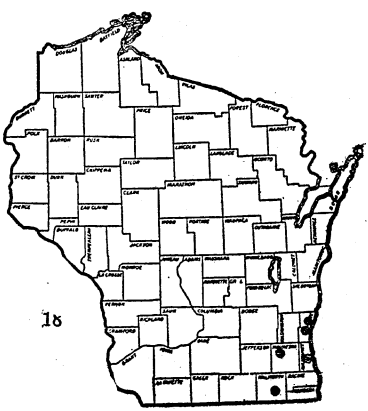
S. rupestris



18

S. apoda

L. CLAVATUM, var. MEGASTACHYON Fernald & Bissell, Rhodora 12: 53. 1910. (Fig. 12). Strictly northern.

L. TRISTACHYUM Pursh. (Fig. 13). Most common northward, in rather dry sandy woodland.

L. COMPLANATUM L.; Victorin l. c. (Fig. 14). The specimens belonging to the *complanatum* group, that were examined, showed such great variation that the question of ecological varieties appears to be important. How much the type of soil affects the depth of the rootstock and the other factors affecting the branch growth is a problem that needs further study. Of the specimens examined, only four fitted the description of the type.

L. COMPLANATUM, var. ELONGATUM Victorin, l. c. (Fig. 15). Most of the Wisconsin material appears to be the var. *elongatum*. It occurs in rather dry woodland and is more common in the northern counties.

L. FLABELLIFORME (Fernald) Blanchard, Rhodora 13: 168. 1911. (Fig. 16). Northern and eastern part of the state, with southern stations in the Dells of the Wisconsin River, and one near Cross Plains, Dane County.

SELAGINELLACEAE

SELAGINELLA SELAGINOIDES (L.) Link. Reported from Sister Bay, Door County, on the basis of a specimen in the Field Museum.[1]

S. RUPESTRIS (L.) Spring. (Fig. 17). Generally distributed in the state, on dry sand or exposed rocks.

S. APODA (L.) Fernald, Rhodora 17: 68. 1915. *S. apus* Spring. (Fig. 18). Restricted to the southeastern counties; occurring along river courses and in damp places.

[1] Steil & Fuller, Am. Fern Journ. 19: 1. 1929.

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. V

CONIFERALES

NORMAN C. FASSETT

More than thirty years ago field data were collected on the distribution of the trees of Wisconsin. Mr. L. S. Cheney, then of the Department of Botany of the University of Wisconsin, now of Barron, Wisconsin, travelled in the years 1897 and 1898 through the state, noting on maps the trees of each region. Descriptions of the species were written, and ranges and uses were discussed; unfortunately this exhaustive treatment of the trees of Wisconsin has never been published. With Mr. Cheney's permission I am making available some of the maps. On the pages following, the ranges indicated by small dots are those determined by Mr. Cheney; the large dots and other symbols represent specimens in the herbaria of the University of Wisconsin, of Iowa State College, and of the Milwaukee Public Museum.

TAXACEAE—YEW FAMILY

TAXUS

T. CANADENSIS Marsh. American Yew. (Fig. 1). Abundant northward; local, mostly on shaded cliffs, southward.

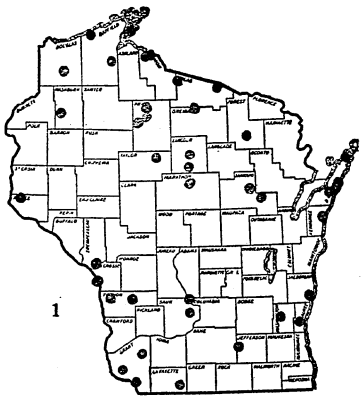
PINACEAE—PINE FAMILY

1. PINUS

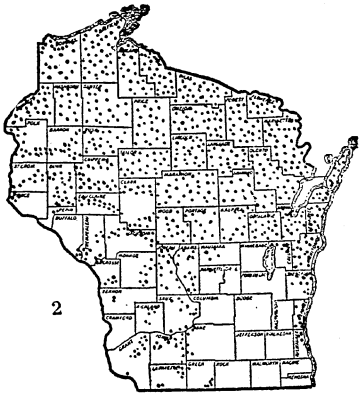
P. STROBUS L. White Pine. (Fig. 2). Mostly northward; southward on rocky bluffs and talus slopes. The cross represents a small grove in Vernon County, not noted by Cheney.

P. BANKSIANA Lamb. Jack Pine. (Fig. 3). To a great extent this pine follows the St. Croixian Sandstone, as do many members of the Ericaceae.[1] A large area of Jack pine also

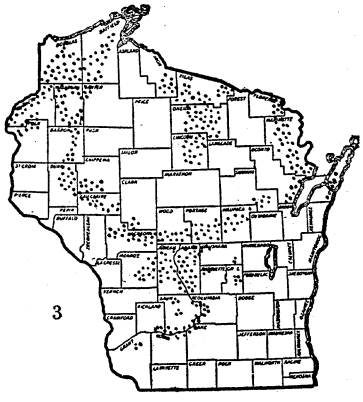
[1] See Fassett, Trans. Wis. Acad. Sci., Arts and Let. 24: 257–268. 1929.



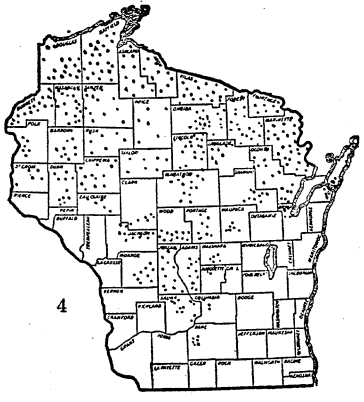
Taxus canadensis



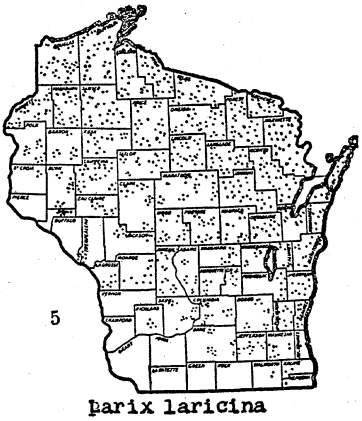
Pinus Strobus



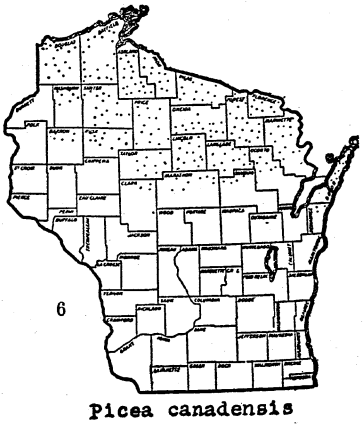
Pinus Banksiana



Pinus resinosa



Larix laricina



Picea canadensis

occurs on the glacial drift of parts of Iron, Vilas, Oneida, and Lincoln Counties.

P. RESINOSA Ait. Red Pine; Norway Pine. (Fig. 4). Abundant northward; more rare on sandy or rocky soil southward.

2. LARIX

L. LARICINA (DuRoi) Koch. Larch; Tamarack. (Fig. 5). Generally distributed in bogs; rare southwestward, where these bogs are rare (see Fassett, l. c.). In this southwestern unglaciated area is shown a small patch of tamarack in the valley of the Pine River in Richland County, and Dr. L. H. Pammel writes me of a tamarack swamp, now destroyed, near La Crosse, where he has found cranberry, blueberry, leatherleaf, and wintergreen, none of which were reported by me in the paper referred to above, on the heaths of Wisconsin.

3. PICEA

P. CANADENSIS (Mill.) BSP. White Spruce. (Fig. 6). Northern. Cheney's manuscript says, "The white spruce in Wisconsin selects a rich soil near streams, lakes, and borders of swamps, or in deep moist forests, where it grows with the balsam, the birch, and many other deciduous trees."

P. MARIANA (Mill.) BSP. Black Spruce. (Fig. 7). Northern, in bogs.

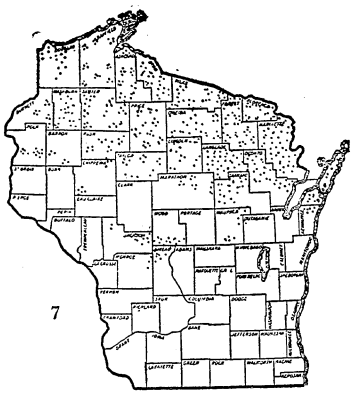
4. ABIES

A. BALSAMEA (L.) Mill., including var. *macrocarpa* Kent. Balsam Fir. (Fig. 8). Mostly northward, extending south along the Wisconsin River to the Dells. Often planted southward.

5. TSUGA

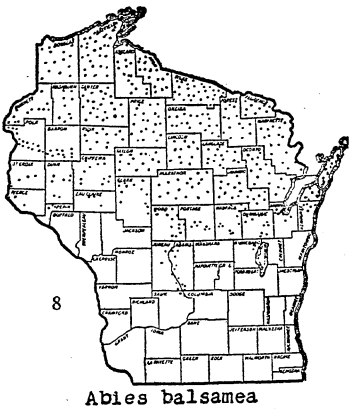
T. CANADENSIS (L.) Carr. Hemlock. (Fig. 9). Cheney writes:

> In Wisconsin, the limits of distribution of this tree are rather well marked; it occurs in a very narrow strip along the St. Louis River and Lake Superior in Douglas and Bayfield Counties, extending south in the latter along the western shore of Chequamegon Bay and the eastern border of the county well toward the south end, where it unites with the great hemlock area of the state. This area includes the western portion of



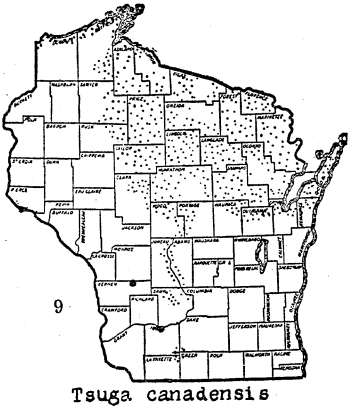
7

Picea mariana



8

Abies balsamea



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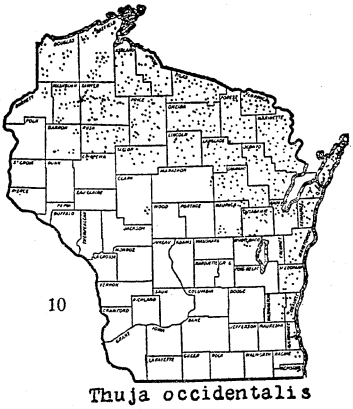
Tsuga canadensis



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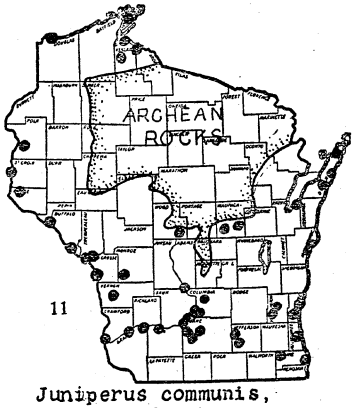
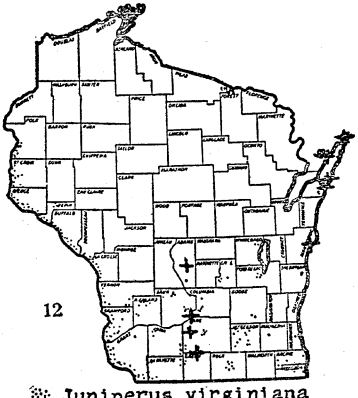
Thuja occidentalis



11

Juniperus communis,
var. depressa



12

⁘ Juniperus virginiana
\+ Juniperus horizontalis

Ashland County, the eastern half of Sawyer, the northern two-thirds of Chippewa, all of Taylor and the northeastern third of Clark County. To the south, it extends over the northern third of Wood, northwestern Portage, along the south line of Marathon, into a little of the northeast corner of Waupaca, the northern third of Outagamie, and the northern half of Brown and Kewaunee Counties. Locally the tree is distributed southward along the Wisconsin River and some of its tributaries through Adams, Juneau, Columbia, Sauk and Iowa Counties. In the extreme southeastern corner of the last-named county a small grove of this tree covers the face of a rocky bluff along the Pecatonica River; in former years, according to statements of the old settlers, considerable merchantable hemlock was cut from the bluffs along the upper course of this small stream, almost to its source near the present towns of Blue Mounds and Ridgeway, in Dane and Iowa Counties.

Collections from Ontario, Vernon Co. (in herb. Univ. of Minn.) and Iowa Co. opposite Lone Rock (in herb. Univ. of Wis.) are shown by large dots.

6. THUJA

T. OCCIDENTALIS L. Arbor Vitae; White Cedar. (Fig. 10). Northern; southward along the Lake Michigan shore.

7. JUNIPERUS

J. COMMUNIS L. The aborescent form of this species is rare in Wisconsin; Mr. Cheney writes me he has not observed it. It was collected at Prescott, Pierce County, by Dr. J. J. Davis in 1914, and by the writer in 1927. The single tree observed by me was about 4 m. tall, with a trunk 15 cm. in diameter; it was on a sandstone bluff about a mile from Lake St. Croix, in Section 2, T. 26 N., R. 19 W.

J. COMMUNIS, var. DEPRESSA Pursh. Common Juniper. (Fig. 11). Like *Alisma Plantago-aquatica*[2] and *Sparganium eurycarpum* (see page 185 of this volume) the juniper seems to avoid the granitic rocks of north-central Wisconsin. As to whether it is actually the underlying rock, or some other factor, which controls this type of distribution, the writer is not ready to state any theory.

Certain shrubs common on the bluffs of northwestern Dane County and adjacent Sauk and Columbia Counties have short, broad, curved needles and seem to approach var. *montana* Ait.

[2] See Fassett, l. c., page 253, fig. 16.

J. HORIZONTALIS Moench. Creeping Juniper. (Fig. 12, crosses). Lake Michigan shores; rarely inland, usually on crumbling sandstone bluffs. Russel says,[3] "Reported by T. Bruhin. Not now found in [Milwaukee] county."

J. VIRGINIANA L. Red Cedar. (Fig. 12, small dots). Cheney says of this:

> Within Wisconsin this plant is a small tree or frequently a shrub. It occurs most abundantly along the Mississippi River; it is also found in all counties along the St. Croix River through Polk County. It is native in La Fayette, Iowa, Green, Dane, Sauk, Columbia, Adams, Rock, Jefferson, Waukesha, Racine, Kenosha, Milwaukee, Sheboygan, Vilas, and Forest Counties. It occurs spontaneously in many other parts of the state, but in these localities it has probably grown from seed scattered from cultivated trees. Such stations were observed in Crawford, Vernon, Richland, Columbia, Dodge, Fond du Lac, and Winnebago Counties.

Mr. J. S. Bordner, of the Wisconsin Economic Land Survey, who in 1929 surveyed Vilas County, states that he saw no red cedar in that region.

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[3] Bull. Wis. Nat. Hist. Soc. 5: 170. 1907.

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. VI

PANDANALES

NORMAN C. FASSETT

The following discussions are based upon specimens in the herbaria of the University of Wisconsin and of the Milwaukee Public Museum.[1]

TYPHACEAE

TYPHA LATIFOLIA L. General throughout the state, but not as common as might be expected in the Mississippi and Lower Wisconsin River bottoms, although occasional colonies may be found in these regions.

T. ANGUSTIFOLIA L. Collected only at Lake Wingra, Madison, although the writer is reasonably sure that stands seen in the marshes in the eastern part of the city, between Lakes Mendota and Monona, belong to this species. Collected as follows: Dane Co.; near Lake Wingra, Madison, July 4, 1922, *R. H. Denniston;* Lake Wingra marsh, July 7, and August 3, 1929, *N. T. Bobb.*

T. ANGUSTIFOLIA, var. ELONGATA (Dudley) Wiegand, Rhodora 26: 1. 1924. Dane Co.; Lake Wingra marsh, Madison, August 3, 1929, *N. T. Bobb.*

During the summer of 1929, Professor N. T. Bobb, of Northland College, made an intensive study of the cattails of Lake Wingra marsh. He writes, in part,[2]

---

[1] It is fortunate that the two largest herbaria of Wisconsin duplicate to a very limited degree the regions covered. The University collections, for example, are the more complete northwestward, while the northeast quarter of the state is better represented in the Museum collections. The writer wishes here to record his indebtedness to Dr. H. H. Smith, Curator, and Mr. A. M. Fuller, Assistant Curator, of the Herbarium of the Milwaukee Public Museum, for their courtesies in making available to him, when in Milwaukee, the excellent facilities of the Museum, and for their many loans of herbarium specimens.

[2] "Typha of the Lake Wingra marsh." Unpublished.

Another intermediate found growing in the Wingra marsh along with angustifolia, but differing from it in having a pistillate spike of darker color and slightly smaller diameter in proportion to its length, seems to check exactly with the herbarium specimen *Typha angustifolia* var. *Calumetensis* Peattie from Lake County Indiana [August 16, 1927, *Fassett* no. 5633, from the type station of var. *Calumetensis*,[3] according to Mr. F. J. Macbride].

There are also several clumps of intermediates growing in the Wingra marsh which are 6 or more feet tall; have the long spike and narrow leaves of *elongata*, but the spike is smaller in diameter, darker in color, and has a tendency to develop few or no bractlets.

After numerous observations of *Typha* in the Wingra marsh, both in the field and more careful examination in the laboratory and from references to the intermediate types, the writer strongly suspects that some if not all of the intermediate types growing in the Lake Wingra marsh have had their origin by crosses between the species, latifolia and angustifolia.

The species and varieties of *Typha*, as they occur in Wisconsin, may be recognized, when typical, as follows:[4]

a. Stem stout; leaves flat; staminate and pistillate portions of spike usually contiguous; pistillate portion of spike dark brown with black markings; pistillate flowers without bractlets; stigma spatulate; fruit furrowed; pollen grains in 4's ---------- *T. latifolia*

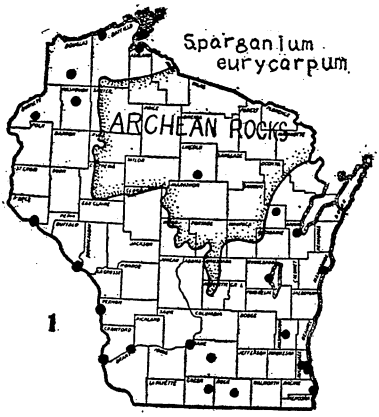
a. Stem slender; leaves convex on the back; staminate and pistillate portions of the spike usually distant, the interval being at least 5 mm.; pistillate portion of spike light or cinnamon brown without black markings; pistillate flowers with bractlets; stigma filiform; fruit not furrowed; pollen grains single *b*

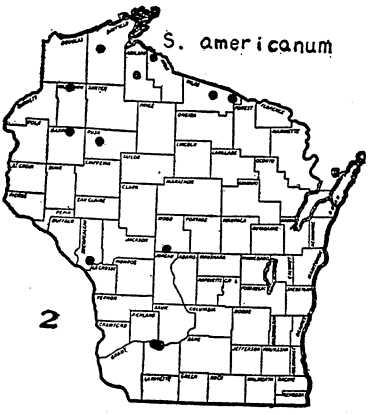
b. Plant 1–1.5 m. tall; lower leaves 3–7 mm. wide; pistillate portion of spike 8–13 cm. long and 10–17 mm. thick in fruit ---------- *T. angustifolia*

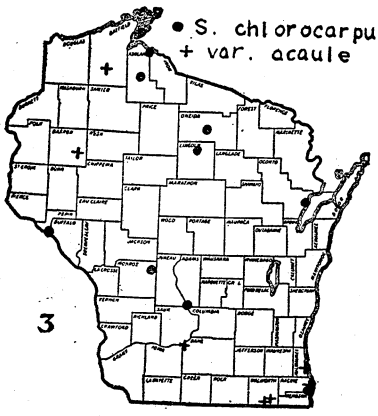
b. Plant 2–3.5 m. tall; lower leaves 9–15 mm. wide; pistillate portion of spike 15–25 (30) cm. long and 20–23 mm. thick in fruit ---------- *T. angustifolia*, var. *elongata*

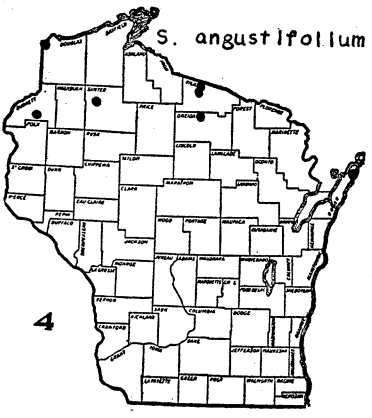
[3] Peattie, Am. Midland Nat. **10**: 129. 1926. Other collections apparently matching this variety, which in my opinion is no more than an extreme phase of *T. angustifolia*, standing out clearly from the individuals which are intermediate with *T. latifolia*, are: Marpath, Ontario, *Geo. L. Fisher;* Woolwich, Maine, *Fassett* no. 3791; Damariscotta Mills, Maine, *Fassett* no. 2470—N. C. F.

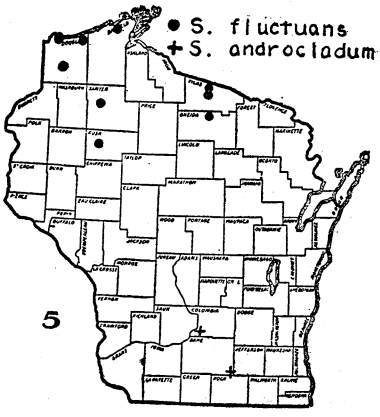
[4] Key largely compiled from Bobb, l. c., and Wiegand, l. c.

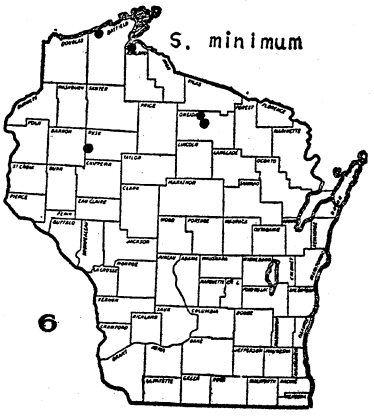

Sparganium
eurycarpum
ARCHEAN ROCKS
1


S. americanum
2


S. chlorocarpum
+ var. acaule
3


S. angustifolium
4


S. fluctuans
+ S. androcladum
5


S. minimum
6

SPARGANIACEAE

SPARGANIUM EURYCARPUM Engelm. (Fig. 1). The distribution of this species appears to be similar to that of *Alisma Plantago-aquatica*[5] in that it is absent from the granites of northern Wisconsin, although it is found to the north, east, south, and west of this mass. An apparent exception, in this case, occurs in the presence, in the Milwaukee Public Museum, of a specimen collected at Merrill, June 25, 1915, *Charles Goessl* no. 760. This is shown on the map by a dot in southern Lincoln County. I am told by Mr. H. R. Aldrich, Assistant State Geologist, that the Wisconsin River at this point cuts through some basic igneous rocks, which may explain the occurrence of the *Sparganium*. It should, therefore, be watched for on other outcrops of this kind throughout north-central Wisconsin.

This is the only representative of the genus occurring commonly along the Mississippi River, whose water is probably too high in lime content for the other species.

S. ANDROCLADUM (Engelm.) Morong; Fernald, Rhodora 24: 27. 1922. *S. simplex*, var. *androcladum* Engelm.; not *S. americanum*, var. *androcladum* Fernald & Eames; Robinson & Fernald in Gray's Manual, ed. 7. *S. lucidum* Fernald & Eames; Robinson & Fernald, l. c. (Fig. 5, crosses). Fernald, l. c., says of the range of this species:

"Abundant in eastern Missouri and adjacent Illinois, it is apparently unknown or at least unrecorded in the region between the Mississippi Valley and eastern Pennsylvania."

The discovery of this plant in Wisconsin is, then, an extension of range from southern Illinois. Collections are as follows: Columbia Co.: wet shore of pool at foot of Gibraltar Rock, Lodi, *Fassett* no. 2889 (identified by Mr. C. A. Weatherby). Dane Co.: muck shore of Turtle Lake, Albion, *Fassett* no. 7582. Both of these stations are on kettle-hole lakes toward the margin of the terminal moraine of the Green Bay lobe of the Wisconsin ice sheet.

S. AMERICANUM Nutt. (Fig. 2). Mostly northward and westward.

S. CHLOROCARPUM Rydb.; Fernald, Rhodora 24: 29. 1922. *S. diversifolium* Fernald & Eames; Robinson & Fernald in

[5] See Trans. Wis. Acad. Sci., Arts & Let. 24: 253, map 16. 1929.

Gray's Manual, ed. 7, probably not of Graebner. (Fig. 3, crosses). Scattered, and freely passing into the more dwarf var. ACAULE (Beeby) Fernald l. c. (*S. diversifolium*, var. *acaule* Fernald & Eames). (Fig. 3, dots).

S. ANGUSTIFOLIUM Michx. (Fig. 4). In northern Wisconsin. An immature specimen, apparently of this species, is from Dunkirk, Dane County, *S. H. Watson.* This is from the herbarium of T. J. Hale, and is labelled in Hale's hand; Hale was active just before the Civil War, and we have no recent collection to substantiate this old doubtful record of *S. angustifolium* from southern Wisconsin.

S. FLUCTUANS (Morong) Robinson. (Fig. 5, dots). In lakes of northern Wisconsin.

S. MINIMUM Fr. (Fig. 6). In boggy places northward. A sheet labelled "St. Croix" by T. J. Hale may be from somewhere along the St. Croix River.

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. VII

BETULACEAE

NORMAN C. FASSETT

The maps representing the distribution of the members of this family in Wisconsin were compiled from two sources. The small-dotted maps illustrating the ranges of the trees are from those of Mr. L. S. Cheney (see page 177); the large dots and other symbols represent localities taken from sheets in the herbaria of the University of Wisconsin and of the Milwaukee Public Museum.

1. CORYLUS

C. AMERICANA Walt. Hazelnut. (Fig. 1). General.

C. CORNUTA Marsh. Arb. Am. 37. 1785. *C. rostrata* Ait. Hort. Kew. 3: 364. 1789. Beaked Hazelnut. (Fig. 2). Mostly northward, coming south along the Lake Michigan shore and in such cool localities as the Dells of the Wisconsin River and Baraboo Bluffs. This is recorded from Milwaukee County as being not so common as *C. americana.*[1] In his flora of Racine and Kenosha Counties, Wadmond[2] says, "Rare or extinct; leaves of this hazel in Dr. Davis herbarium infected by a Septoria, collected near Horlicksville, Racine County. Station now destroyed. Not seen elsewhere."

2. OSTRYA

O. VIRGINIANA (Mill.) K. Koch. Ironwood; Hop Hornbeam. (Fig. 3). Cheney records this from every county except Buffalo, Trempealeau, and Jackson. Three localities from which he did not record the presence of this tree are now represented by herbarium specimens; each is indicated on the map by a cross.

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[1] Russel, Bull. Wis. Nat. Hist. Soc. **5**: 186. 1907.

[2] Trans. Wis. Acad. Sci., Arts and Let. **16**: 826, 827. 1909.

O. VIRGINIANA, var. GLANDULOSA (Spach) Sarg. Bot. Gaz. 67: 216. 1919. This variation with stalked glands on the branchlets, etc., is stated by Rehder to be the northern form of the species.[3] It is scattered throughout Wisconsin, being about as common as the glandless type.

3. CARPINUS

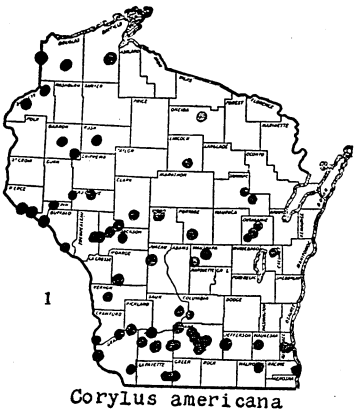
C. CAROLINIANA Walt. Blue Beech; Hornbeam; Ironwood. (Fig. 4). Common northeastward; mostly along the rivers southwestward. Two localities not shown by Cheney, but now represented by herbarium specimens, are indicated by crosses.

3. BETULA

The members of this genus occurring in Wisconsin may be distinguished as follows:

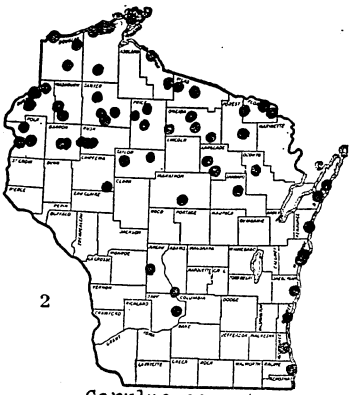
a. Scales of fruiting catkins persistent; leaves with impressed veins *b*	
b. Leaf-blades obliquely subcordate at base, more or less tapering at tip *c*	
c. Scales of fruiting catkins less than 8 mm. long	*B. lutea*
c. Scales of fruiting catkins 8 mm. or more long	*B. lutea*, var. *macrolepis*
b. Leaf-blades at base tapering to the petiole, acute at tip	*B. nigra*
a. Scales of the fruiting catkins deciduous; veins not impressed *d*	
d. Trees; leaf-blades 6–10 cm. long *e*	
e. Leaf-blades rounded to subcuneate at base	*B. papyrifera*
e. Leaf-blades cordate at base	*B. papyrifera*, var. *cordifolia*
d. Shrubs; leaf-blades 2–6 cm. long *f*	
f. Leaves with 5–7 pairs of veins; fruiting catkins short-stalked or sessile; scales 5.5–7 mm. long, ciliate	*B. Purpusii*
f. Leaves with 3–5 pairs of veins: fruiting catkins distinctly stalked; scales 3–5.5 mm. long	
g. Leaf-blades rhombic-ovate to abovate; fruiting catkins 2–3 cm. long; scales 4–5.5 mm. long; wing as wide as or wider than the nutlet	*B. Sandbergii*
g. Leaf-blades obovate to oval; fruiting catkins 1–2.8 cm. long; scales 3–3.5 mm. long; wing narrower than the nutlet	*B. pumila*, var. *glandulifera*

[3] Man. Cult. Trees and Shrubs 151. 1927.



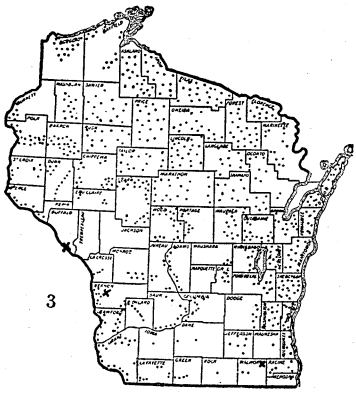
1

Corylus americana



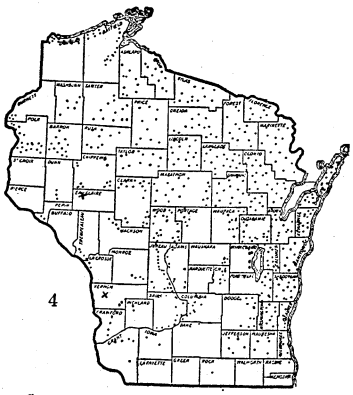
2

Corylus cornuta



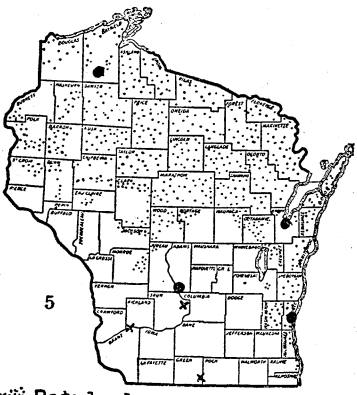
3

Ostrya virginiana



4

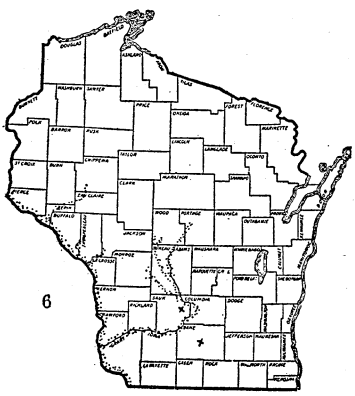
Carpinus caroliniana



5

× Betula lutea

● B. lutea, var. macrolepis



6

Betula nigra

B. LUTEA Michx. f. Yellow Birch. (Fig. 5, small dots, and crosses). Mostly northward. Certain localities, not accredited with this species by Cheney, but where collections have been made, are shown by crosses.

B. LUTEA, var. MACROLEPIS Fernald, Rhodora 24: 170. 1922. (Fig. 5, large dots). Occasional.

Certain individuals of yellow birch have close dark brown bark simulating that of *B. lenta,* and may have given rise to reports of black birch in Wisconsin. The latter species has not been found native in the state.

B. NIGRA L. Red Birch; River Birch. (Fig. 6). Mostly confined to river-bottoms southward and westward. It has also been collected at Devils Lake (indicated by a cross) which is without outlet and not connected with any river system. At Madison (shown by cross) there are a few trees on the western shore of Lake Monona, which are probably escapes from cultivation, since this locality is not shown by Cheney, nor is it listed by Cheney and True in their Flora of Madison and Vicinity.[4]

B. PAPYRIFERA Marsh. *B. alba,* var. *papyrifera* Spach. White Birch. (Fig. 7, small dots). Abundant northward; rare, usually on exposed bluffs, southward.

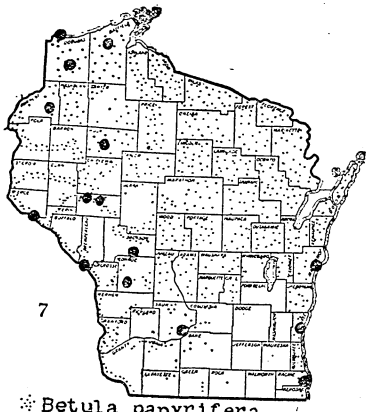
B. PAPYRIFERA, var. CORDIFOLIA (Regel) Fernald. (Fig. 7, large dots). This variety appears to avoid the Archean rocks of north-central Wisconsin, as does *Juniperus communis,* var. *depressa* (see map 11, page 180). This apparent fact should be regarded as questionable until it can be further checked in the field, since Cheney did not differentiate this variety.

B. PURPUSII Schneider, Ill. Handb. d. Laubholzk. 1: 102. 1904. *B. lutea* X *pumila* var. *glandulifera* Rosendahl, Minn. Bot. Stud. 4: 456. 1916; Rhodora 30: 125. 1928. (Fig. 8). Milwaukee, collected by I. A. Lapham (see Rhodora 31: 51. 1929).

B. SANDBERGII Britton, Bull. Torr. Bot. Club. 31: 166. 1904; Rosendahl, Rhodora, l. c. *B. papyrifera* X *pumila* var. *glandulifera* Minn. Bot. Stud. 4: 454. 1916. (Fig. 9). Scattered.

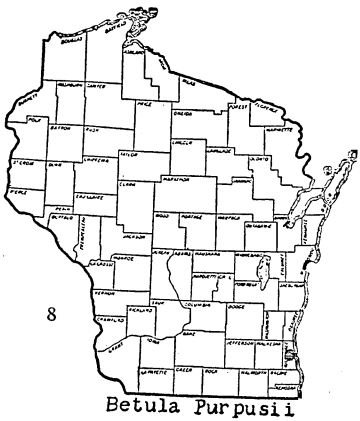
B. PUMILA L., var. GLANDULIFERA Regel; Rosendahl, Minn. Bot. Stud. 4: 458. 1916; Rhodora 30: 125–129. 1928. Swamp Birch. (Fig. 10). According to Rosendahl, typical *B. pumila,*

[4] Trans. Wis. Acad. Sci., Arts and Let. 9: 98. 1893.



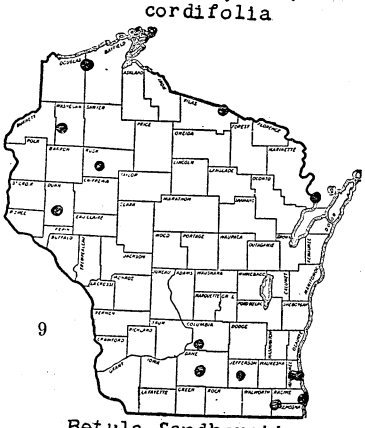
7

⁘ Betula papyrifera
● B. papyrifera, var. cordifolia



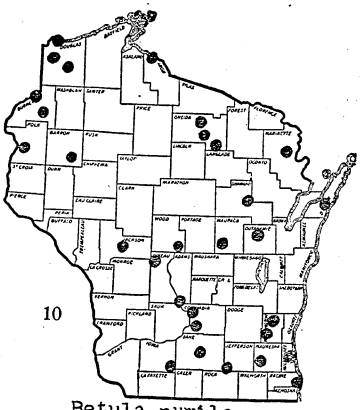
8

Betula Purpusii



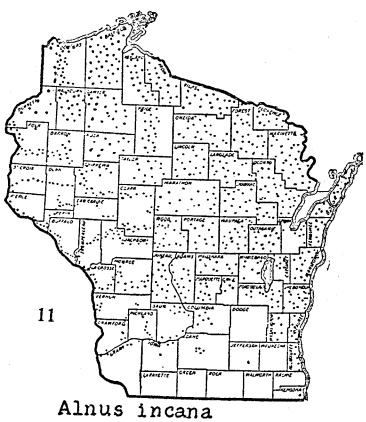
9

Betula Sandbergii



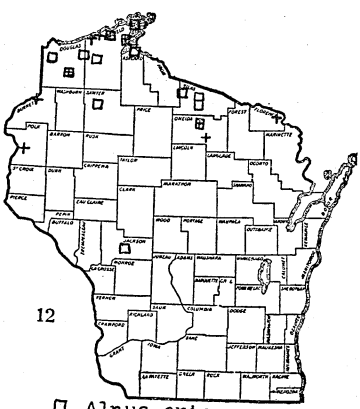
10

Betula pumila, var. glandulosa



11

Alnus incana



12

□ Alnus crispa
+ A. crispa, var. mollis

13

a plant with the young branchlets densely pubescent, is unknown in this region. On the other hand, Wadmond (l. c.) records *B. pumila* from Wind Lake, Racine County, and says of var. *glandulifera,* "This variety in its long pubescence, suggests B. pumila; but mixed with the pubescence, and sometimes upon the leaves, are the characteristic glandular atoms of B. glandulosa." The only middle western material which appears to me to match the typical *B. pumila* of the east is a sheet from Millers, Indiana, June 11, 1898, H. C. Powell.

5. ALNUS

A. INCANA (L.) Moench. Speckled Alder. (Fig. 11). Common northward; rare southward.

A. CRISPA (Ait.) Pursh. *A. viridis* (Chaix.) DC., var. *crispa* (Ait.) House, N. Y. State Mus. Bull. 254: 271. 1924. Green Alder. (Fig. 12, squares). Northern. Grading into the next.

A. CRISPA, var. MOLLIS Fernald, Rhodora 15: 44. 1913. *A. mollis* Fernald. *A. viridis,* var. *Fernaldii* House, l. c. (Fig. 12, crosses). Northern.

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. VIII

ACERACEAE

NORMAN C. FASSETT

The distribution maps of the arborescent maples here presented are taken from those prepared by Mr. L. S. Cheney (see page 177). The range of *Acer spicatum* is compiled from specimens in the herbaria of the University of Wisconsin, of the Milwaukee Public Museum, and of Iowa State College.

ACER

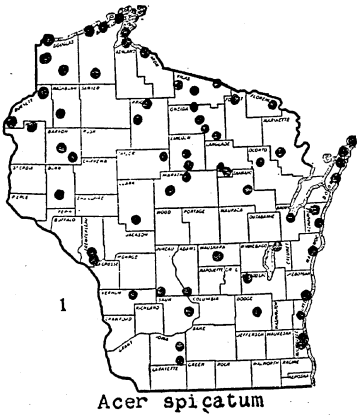
A. SPICATUM Lam. Mountain Maple. (Fig. 1). Common northward, less common southward.

A. SACCHARUM Marsh., including var. *glaucum* (Pax) Sarg., and var. *Schneckii* Rehd. Sugar Maple; Rock Maple. (Fig. 2). Cheney records this as being probably indigenous to every county in the state. He does not show it in some of the counties bordering the Mississippi River, but I have collected it at Minneiska, Minnesota, across the river from Cochrane, Buffalo County.

The sugar maple is absent from the barrens of Burnett, Douglas, and Bayfield Counties, and on the sand plains of Juneau, Adams, and parts of Wood and Portage Counties is present only along the Yellow River. It will be seen that these regions are where *Pinus Banksiana* is most abundant (see fig. 3, page 178). In Vilas, Oneida, and Lincoln Counties these two trees grow together, but I am told by Mr. W. W. Morris of the Economic Land Survey that the maple makes but a poor growth in this region.

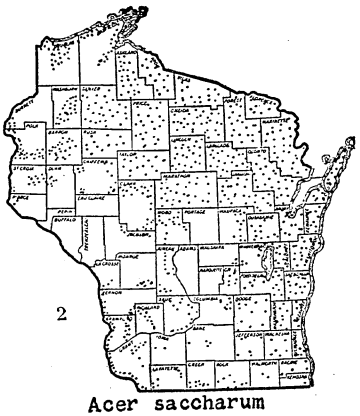
A. SACCHARUM, var. NIGRUM (Michx. f.) Britton. *A. nigrum* Michx. f. Black Maple. (Fig. 3). General, except southwestward. Wadmond records it as being frequent in Racine and Kenosha Counties.[1] Cheney says in his manuscript,

[1] Trans. Wis. Acad. Sci., Arts and Let. **16**: 850. 1999.



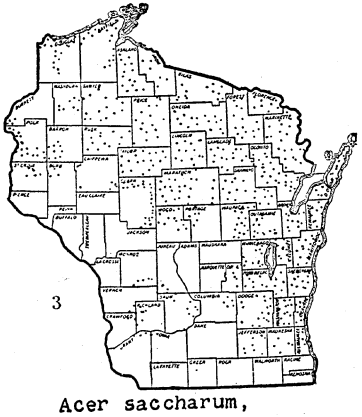
1

Acer spicatum



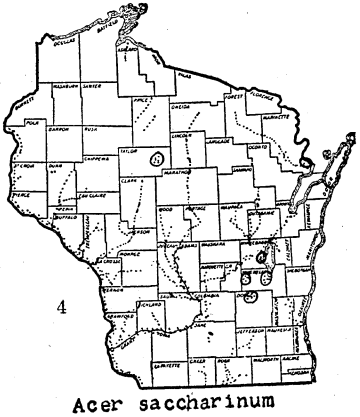
2

Acer saccharum



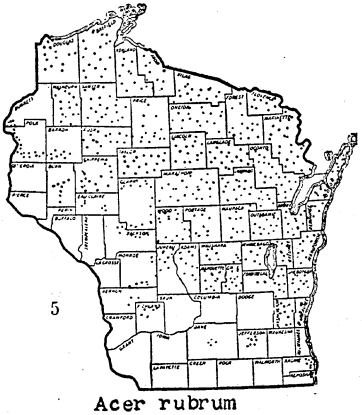
3

Acer saccharum,
var. nigrum



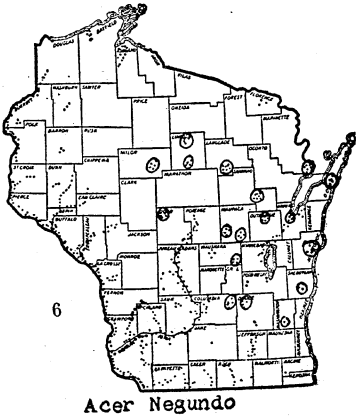
4

Acer saccharinum



5

Acer rubrum



6

Acer Negundo

"In Wisconsin this variety is not as distinctly marked as it appears to be further east and south. This is especially true of the lobing of the leaves; our forms have many five-lobed ones."

A. SACCHARINUM L. Silver Maple. (Fig. 4). In Wisconsin, mostly along river-bottoms. The regions on the map enclosed by small circles are those in which Cheney noted this tree as being introduced. Recorded from Milwaukee County only as a planted shade tree. Wadmond (l. c.) says of the silver maple in Racine and Kenosha Counties, "Common: well-known in cultivation and well-established as an escape. There are some splendid specimens of the Silver Maple along the upper Root River, though these perhaps are not native."

A. RUBRUM L. Red Maple. (Fig. 5). Rare westward. Cheney does not record this from Milwaukee County, but Russel[2] says, "Throughout the county. Not uncommon."

A. NEGUNDO L., including var. *violaceum* Kirchn. Box Elder. (Fig. 6). More common southwestward. Localities enclosed by small circles are where this tree was noted by Cheney as having been introduced. Occasionally escaped from cultivation in Milwaukee,[2] Racine,[3] and Kenosha Counties.

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[2] Russel, Bull. Wis. Nat. Hist. Soc. 5: 209. 1907.
[3] Wadmond, l. c.

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. IX

ELATINACEAE—WATERWORT FAMILY

NORMAN C. FASSETT

ELATINE MINIMA (Nutt.) Fisch. & Meyer; Fernald, Rhodora **19**: 13. 1917. *E. americana* Am. Auth. in part, not *Peplis americana* Pursh. (Fig. 1). Probably common in sandy lakes of northern Wisconsin, but usually overlooked. See pages 161 to 167 for a discussion of the ecology of this species in Vilas County. Peattie lists this as an essentially coastal plain species,[1] saying, "Does not go far west in New York State. The [A] specimen is in the Gray Herbarium from Chisago, Minn."

ELATINE TRIANDRA Schkuhr; Fernald, l. c. (Fig. 2, dot). In a great arc, roughly 100 miles long, the Johnstown Moraine runs through south-central Wisconsin.[2] As is frequently the case in such moraines, there are many kettleholes; some of these are dry, but others have standing water, and in spite of the utilization of these small ponds for watering cattle or swine, give promise of interesting botanizing. In one of these kettleholes in the terminal moraine ten miles northeast of Kilbourn, *Elatine triandra* was collected in the fall of 1929 by F. M. Uhler, W. T. McLaughlin, and the writer.

The only station east of the Mississippi River listed by Fernald, l. c., is at Skowhegan, Maine, where it may be adventive; the identity of the plant reported under this name from Illinois he says is open to doubt.

The seeds of the Wisconsin plant are identical with those of the eastern *E. americana,* but the leaf is more linear; the writer is led to think that perhaps the latter species might better be treated as a variety of *E. triandra.*

Here both f. *terrestris* Seubert, on muddy shores, and f. *submersa* Seubert, in one dm. of water, are represented. Particularly after being pressed, the leaves of the Wisconsin material

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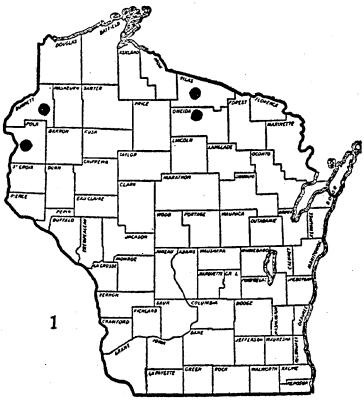
[1] Rhodora **24**: 88. 1922.

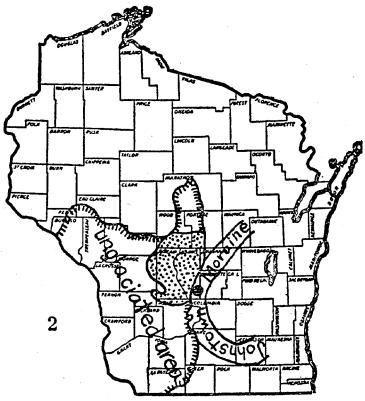
[2] See Alden, U. S. Geol. Surv. Prof. Paper **106**: pl. xxiii. 1918.

of f. *terrestris* tend to become reddish, and are minutely papillate, in this character differing from the few collections of European and western American plants available.

A form in 2-3 dm. of water would have been overlooked had it not been for the zeal of Mr. F. M. Uhler, of the U. S. Biological Survey, in his search for aquatic animal life. In contrast to *E. minima,* which is essentially the same in the water and on the shore, this plant in deeper water becomes coarse, about a decimeter in length, with leaves up to 13 mm. long. It suggests a *Callitriche,* and is probably f. *callitrichoides,* at least as described by Hegi, Ill. Fl. Mitt.-Eu. 5: 539. 1926.



1



2

The station for *E. triandra* lies only a few miles east of the unglaciated area, and the range of the plant is probably to be accounted for on a basis of preglacial widespread distribution. Thus it is in a class with *Montia Chamissoi,*[3] *Sullivantia renifolia,*[4] *Aconitum noveboracense,* var. *quasciliatum,*[5] and *Dodocatheon Meadia,* var. *amethystinum,*[6] and other plants of cordilleran affinities, in the Middle West confined more or less closely to the unglaciated area of Wisconsin and neighboring states. Indeed this kettlehole was probably formed while the glacial Lake Wisconsin[7] was still only a few miles away (fig. 2, stippled area); Lake Wisconsin, now almost completely dried up, may well have captured the aquatic flora of any preglacial lake which it drowned.

[3] See Holzinger, Pl. World **4**: 41–43. 1901.
[4] Rosendahl, Univ. Minn. Stud. Biol. Sci. **6**: 410. 1927.
[5] Fassett, Rhodora **31**: 49–52. 1929.
[6] Fassett, l. c. 51–53.
[7] See Martin, Wis. Geol. and Nat. Hist. Surv. Bull. **36**: pl. vii. 1916.

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. X

HALORAGIDACEAE—WATER MILFOIL FAMILY

NORMAN C. FASSETT

The following distributional maps are compiled from specimens in the herbaria of the University of Wisconsin and of the Milwaukee Public Museum. In neither of these herbaria is the representation of the aquatic plants adequate and these maps must be regarded as being far from complete.

1. MYRIOPHYLLUM—Water Milfoil

M. ALTERNIFLORUM DC. (Fig. 1). Mostly northern; perhaps more common southward than is here indicated.

M. SPICATUM L. *M. exalbescens* Fernald, Rhodora 21: 120. 1919. (Fig. 2, dots). Common southeastward.

M. VERTICILLATUM L. (Fig. 3). Recorded as "rare or local with us" in Gray's Manual, ed. 7, the typical form of this species seems to be not infrequent in Wisconsin.

M. VERTICILLATUM, var. PECTINATUM Wallr. (Fig. 2, crosses). Apparently only in the north.

M. HETEROPHYLLUM Michx. (Fig. 4, dots). Not common.

M. TENELLUM Bigel. (Fig. 4, crosses). Until the summer of 1929 this species was unknown in Wisconsin, but the writer in August made a number of collections in several lakes in Vilas County.[1] He also observed great quantities uprooted by a storm and rolled up on the beach at Cable Lake, near Spooner, Washburn County; unfortunately collections were not made here. *M. tenellum* is probably not uncommon in the sandy lakes of northern Wisconsin, but is overlooked on account of its small size and the depth of water in which it grows.

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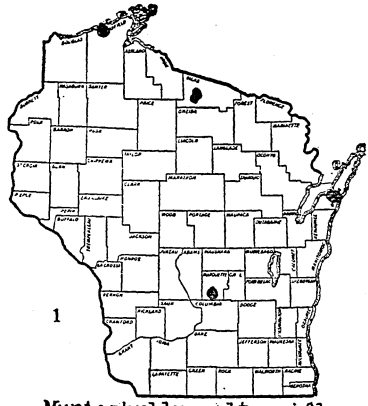
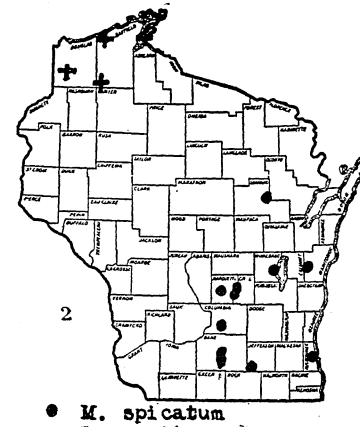
[1] See page 167 of this volume.



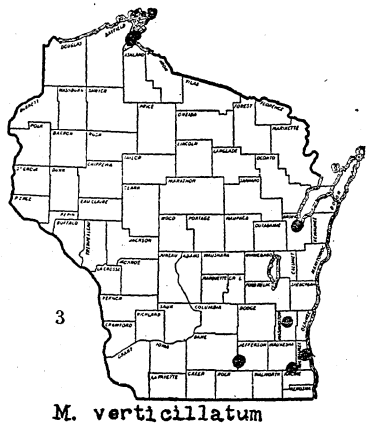
1

Myriophyllum alterniflorum



2

● M. spicatum
✚ M. verticillatum, var. pectinatum



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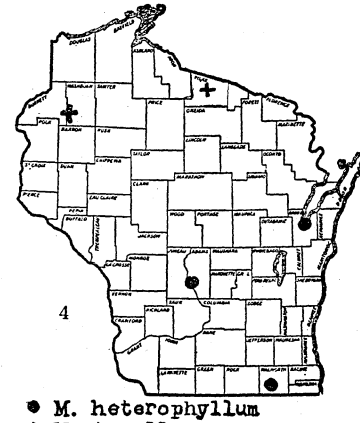
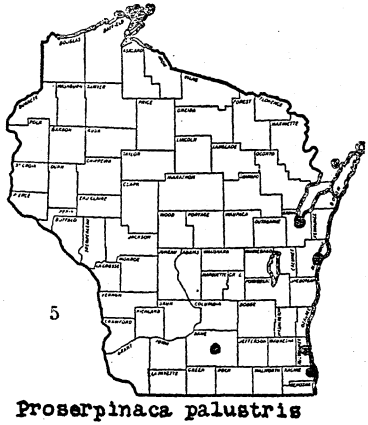
M. verticillatum



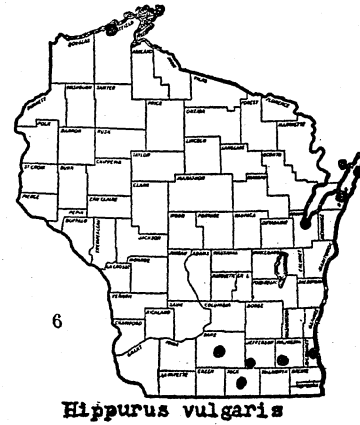
4

● M. heterophyllum
✚ M. tenellum



5

Proserpinaca palustris



6

Hippurus vulgaris

2. PROSPERPINACA—Mermaid-weed

P. PALUSTRIS L. *P. palustris,* var. *amblyogona* Fernald, Rhodora **11**: 120. 1909. (Fig. 5). Eastern; not common.

3. HIPPURUS—Mare's-tail

H. VULGARIS L. (Fig. 6). Mostly southern and eastern, but collected at Port Wing, Bayfield County, by L. S. Cheney in 1897. It was seen at this same locality, in a lagoon back of the sand beach of Lake Superior, by the writer in 1929.

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. XI

RANUNCULACEAE—BUTTERCUP FAMILY

LOIS ALMON

The following list was compiled from data obtained by study of the specimens of Ranunculaceae in the herbaria of the University of Wisconsin and the Milwaukee Public Museum. Determinations of the specimens were carefully checked.

The maps represent the mounted material in these herbaria in June 1929. These maps do not necessarily show the true ranges of the species within the State, for the collections in the two herbaria are geographically incomplete. Also, the number of dots on a map does not necessarily represent the relative abundance of a species; for common species are often overlooked by the collector.

Hence, the only claims made for the list and the maps are that they include, as far as could be ascertained, the species of Ranunculaceae which have been collected in Wisconsin, and some of the localities where they have been found.

It is possible that *Ranunculus hispidus* or a variety of it should have been included in the list. A specimen of J. H. Schuette, labelled Preble, Brown Co., May 21, 1892 was reported by Fernald[1] as *R. hispidus* var. *falsus*. In the Field Museum herbarium a Schuette specimen bearing the above data is filed as *R. septentrionalis*. The original label bears this name. Since the plant is distinctly stoloniferous this determination is probably correct. No other plant with the data of the specimen cited by Fernald was found. Nor has any specimen having the characteristics of *R. hispidus* been found in either of the Wisconsin herbaria.

Following each specific name is given the distribution, in general terms, of the species in Wisconsin as far as could be determined by the available data. Genera and species are arranged alphabetically.

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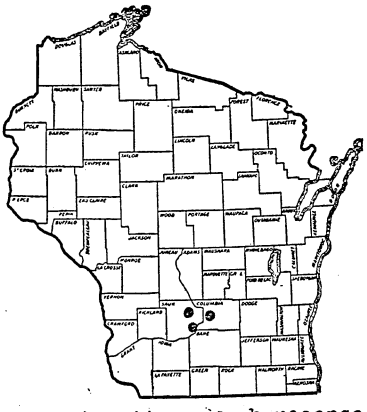
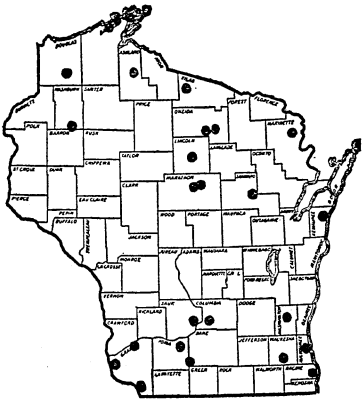
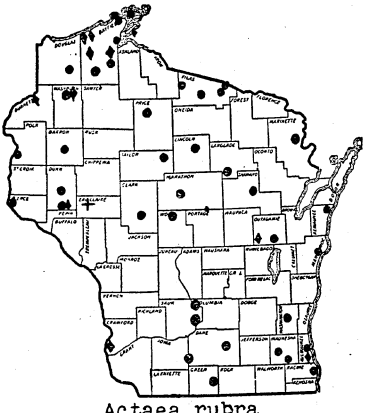
[1] Rhodora **22**: 30. 1920.



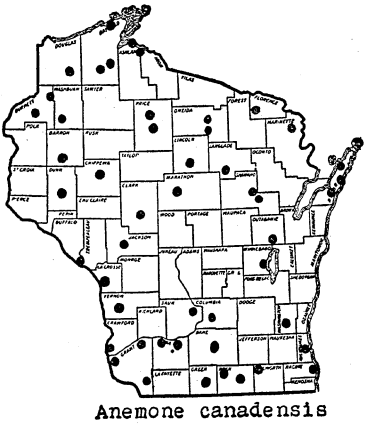
Aconitum noveboracense
var. quasiciliatum



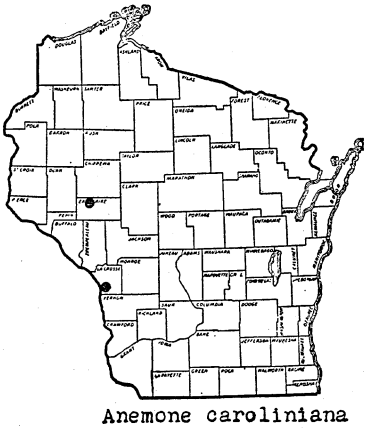
Actaea alba



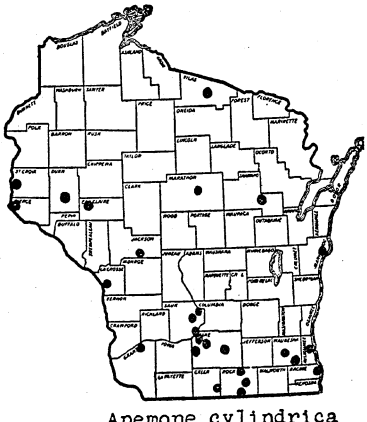
Actaea rubra
+var. gigantea
♦f. neglecta



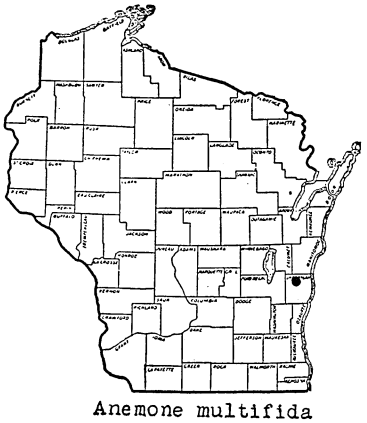
Anemone canadensis



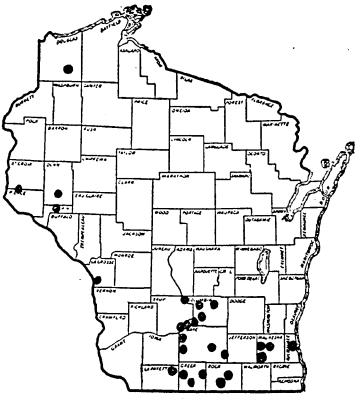
Anemone caroliniana



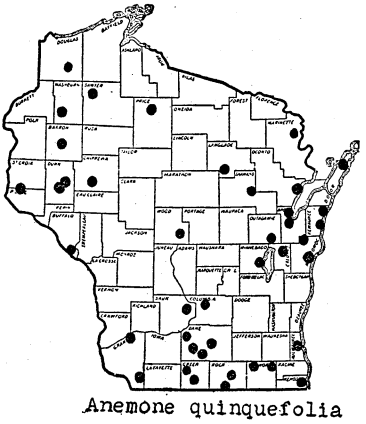
Anemone cylindrica



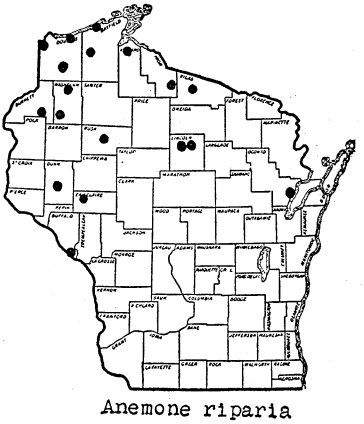
Anemone multifida



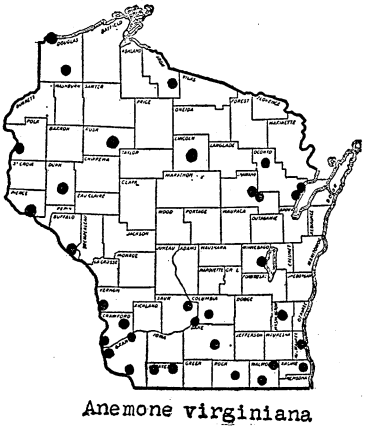
Anemone patens var. Wolfgangiana



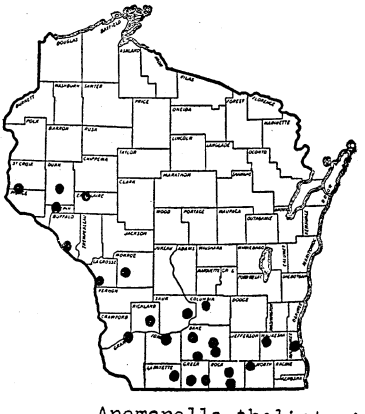
Anemone quinquefolia



Anemone riparia



Anemone virginiana



Anemonella thalictroides

ACONITUM

A. NOVEBORACENSE Gray var. QUASICILIATUM Fassett, Rhodora 31: 49. 1929. Found growing on cliffs at three stations in the unglaciated region.

ACTAEA

A. ALBA (L.) Mill. Generally distributed.
A. RUBRA (Ait.) Willd. Generally distributed.
Forma NEGLECTA (Gillman) Robinson. Generally distributed.
Var. GIGANTEA Gates, Bot. Gaz. 61: 193. 1916. One specimen, collected at Altoona, July 10, 1925, by J. J. Davis.

ANEMONE

A. CANADENSIS L. Generally distributed.
A. CAROLINIANA Walt. West; as though advanced from the prairies.
A. CYLINDRICA Gray. Generally distributed.
A. MULTIFIDA Poir. Only one specimen, collected at Elkhart Lake, July 13, 1913, by A. Sandig. In Milwaukee Public Museum.
A. PATENS L. var. WOLFGANGIANA (Bess.) Koch. Avoids northeast section.
A. QUINQUEFOLIA L. Generally distributed.
A. RIPARIA Fernald, Rhodora 1: 51. 1899; ibid 19: 139. 1917. North.
A. VIRGINIANA L. Generally distributed.

ANEMONELLA

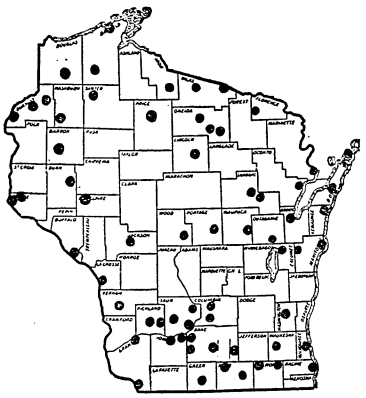
A. THALICTROIDES (L.) Spach. Avoids north and east.

AQUILEGIA

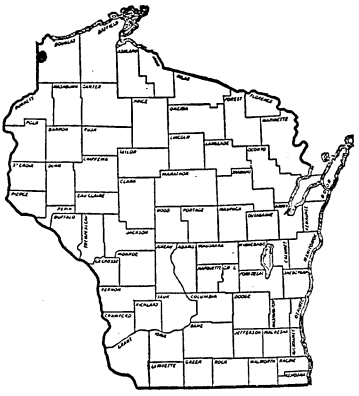
A. CANADENSIS L. Generally distributed.

CALTHA

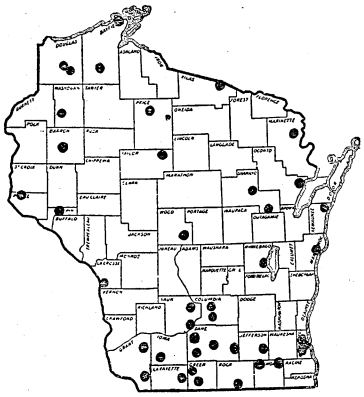
C. NATANS Pall. Several specimens collected at Foxboro, Douglas Co., by Charles Goessl, July 18, 1917.
C. PALUSTRIS L. Generally distributed.



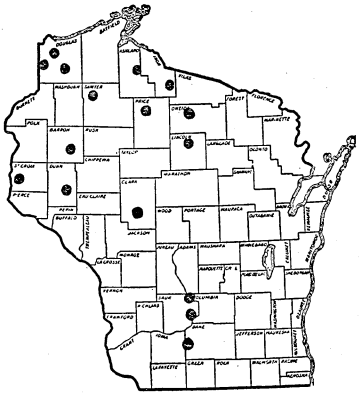
Aquilegia canadensis



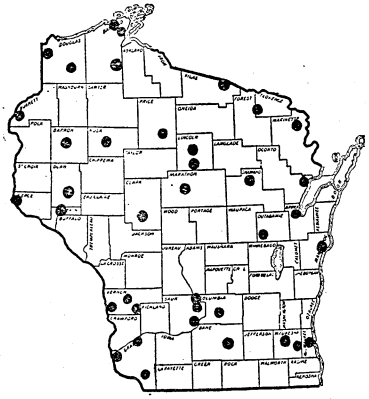
Caltha natans



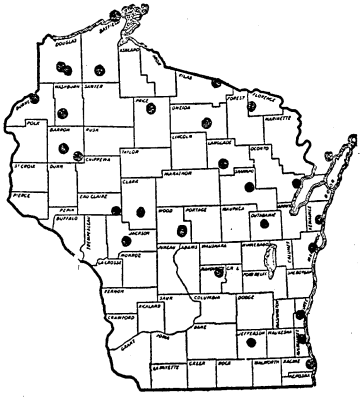
Caltha palustris



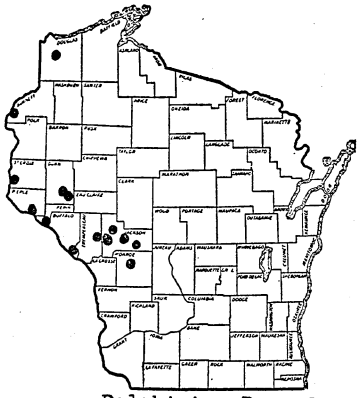
Clematis verticillaris



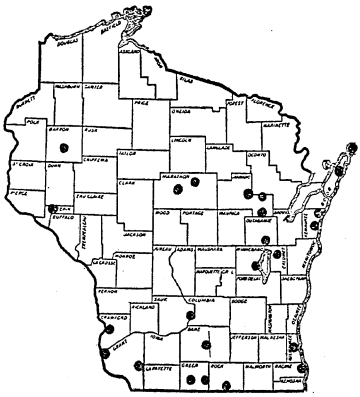
Clematis virginiana



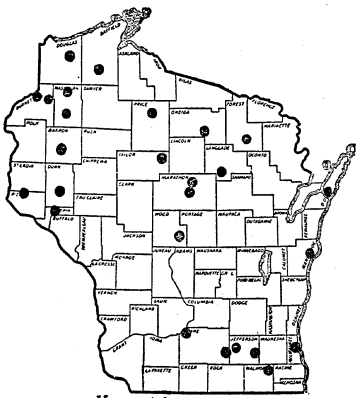
Coptis trifolia



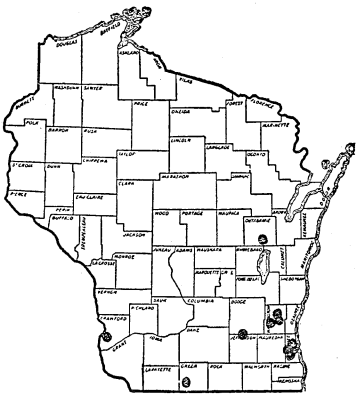
Delphinium Penardi



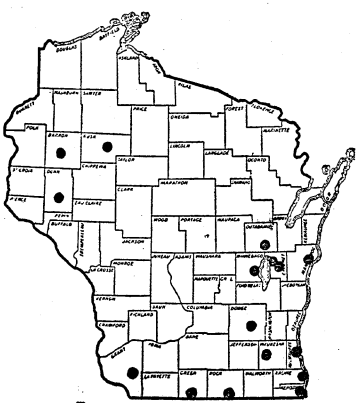
Hepatica acutiloba



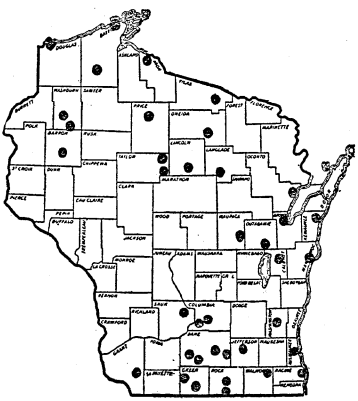
Hepatica americana



Hydrastis canadensis



Isopyrum biternatum



Ranunculus abortivus

CLEMATIS

C. VERTICILLARIS DC. Western half.
C. VIRGINIANA L. Generally distributed.

COPTIS

C. TRIFOLIA (L.) Salisb. Absent from southwest corner.

DELPHINIUM

D. PENARDI Huth. West; as though advanced from the prairies.

HEPATICA

H. ACUTILOBA DC. Absent from extreme north.
H. AMERICANA (DC.) Ker. See Fernald, Rhodora **19**: 45. 1917. Generally distributed.

HYDRASTIS

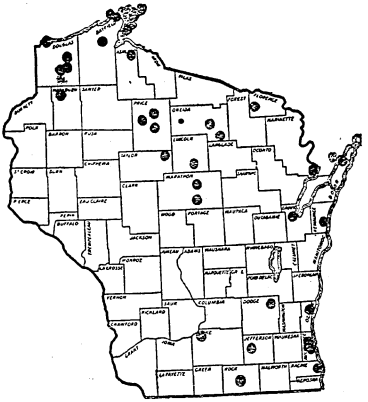
H. CANADENSIS L. South.

ISOPYRUM

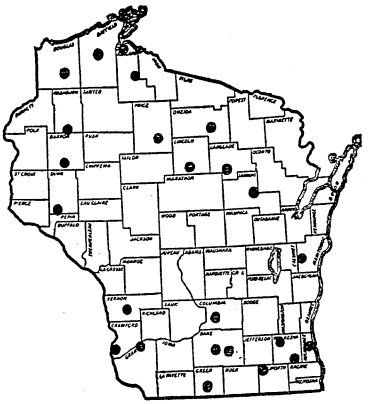
I. BITERNATUM (Raf.) T. & G. Range not well defined. More material needed.

RANUNCULUS

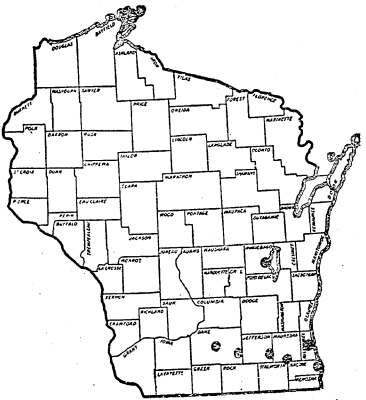
R. ABORTIVUS L. Generally distributed.
R. ACRIS L. Introduced European species, spreading rapidly. At present, absent from western part.
R. AQUATILIS L., var. CAPILLACEUS DC. Generally distributed.
R. CIRCINATUS Sibth. South-east.
R. CYMBALARIA Pursh. Beaches of Lake Michigan. One inland station at Lake Geneva.
R. DELPHINIFOLIUS Torr. Avoids southwest corner.
R. FASCICULARIS Muhl. South.
R. PENNSYLVANICUS L. f. Generally distributed.
R. RECURVATUS Poir. Generally distributed.
R. REPENS L. One specimen, collected at Sturgeon Bay in the Evergreen Nurseries, July 19, 1918, by J. J. Davis.



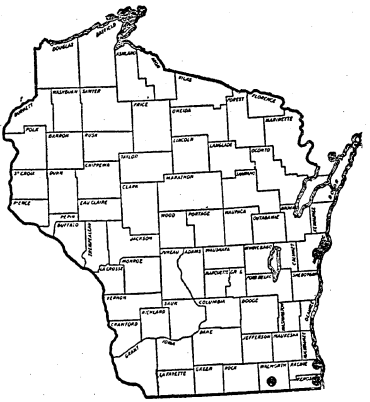
Ranunculus acris



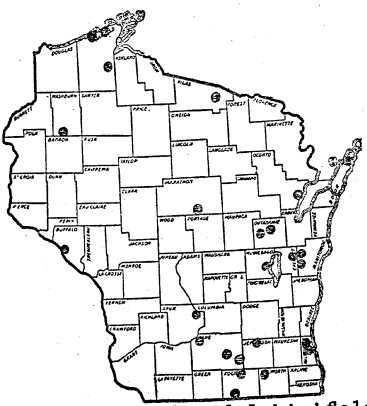
Ranunculus aquatilis var. capillaceus



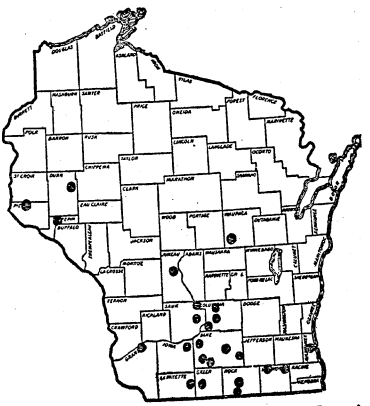
Ranunculus circinatus



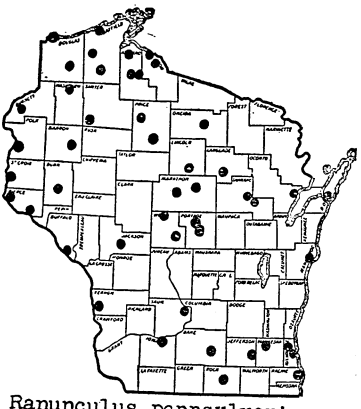
Ranunculus Cymbalaria



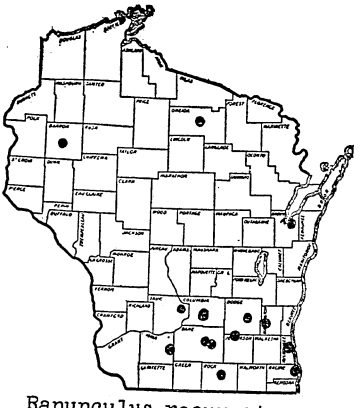
Ranunculus delphinifolius



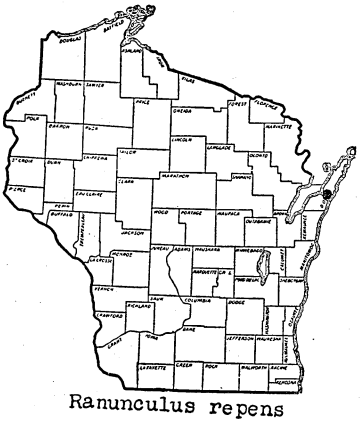
Ranunculus fascicularis



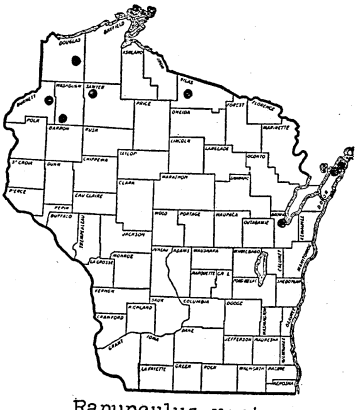
Ranunculus pennsylvanicus



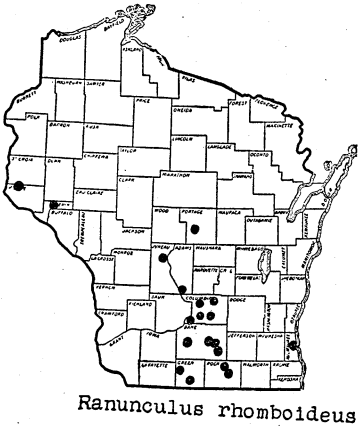
Ranunculus recurvatus



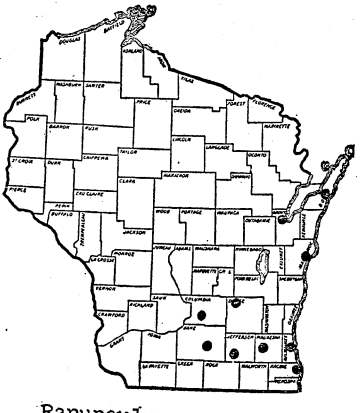
Ranunculus repens



Ranunculus reptans



Ranunculus rhomboideus

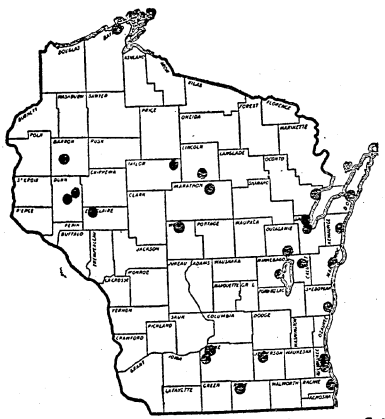


Ranunculus sceleratus

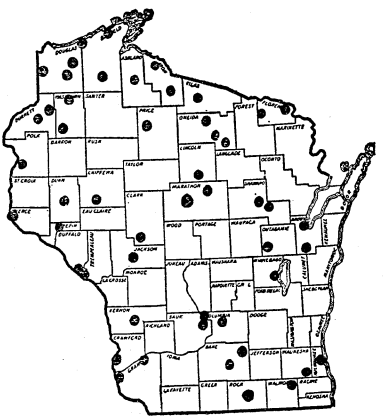
R. REPTANS L. See Rhodora 19: 135. 1917. Includes var. OVALIS (Bigel.) T. & G.; Fernald, l. c. North.
R. RHOMBOIDEUS Goldie. South.
R. SCELERATUS L. East.
R. SEPTENTRIONALIS Poir. Generally distributed.

THALICTRUM

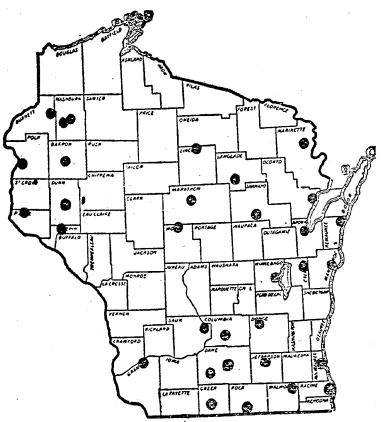
T. DASYCARPUM Fisch. & Lall. Generally distributed.
T. DIOICUM L. Generally distributed.
T. REVOLUTUM DC. Range not well defined. More material needed.



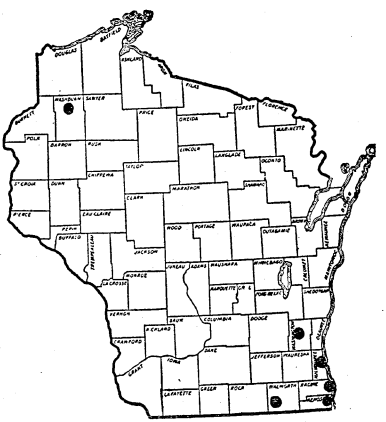
Ranunculus septentrionalis



Thalictrum dasycarpum



Thalictrum dioicum



Thalictrum revolutum

INVESTIGATIONS ON THE NATURE OF PROTOACHLYA PARADOXA COKER

JAMES A. LOUNSBURY
Marquette University

Coker (1923) has already drawn attention to the probable phylogenetic importance of Protoachlya paradoxa. This fungus, manifesting as it does, characters almost intermediate between Saprolegnia and Achlya, would, however, lose much of its significance if it were shown that an individual were but a temporarily aberrant species of one or the other of the genera mentioned above. Those who have worked with the Saprolegniaceae know only too well that individual plants are particularly sensitive to environmental changes. Not infrequently abnormalities or variations in development occur which are difficult to explain on a physical or a nutritional basis. It is within the realm of speculation that an organism, fitting the description for P. paradoxa, might eventually turn out to be a specific member, in a temporarily unstable condition, of one of the more widely recognized genera.

It was with this in mind that the writer began his studies on a culture of the fungus isolated from a sample of water, collected from a stream near Madison, Wisconsin, in the summer of 1927. This was the first time that the writer, in several hundred collections of water molds, had encountered a form which bore sporangia both by cymose branching as in Achlya and also, occasionally, by internal proliferation as in Saprolegnia; and, which, furthermore, discharged zoospores that were either monoplanetic or diplanetic in behavior. Attempts to obtain sexual development were unsuccessful and, for this reason, further interest in the plant was stimulated.

Coker had experienced difficulty in inducing oogonial formation in pure cultures of his plant, in spite of the application of the methods of Klebs (1899) and of Kauffman (1908). It seemed then worth while to study the fungus, not only with a view to determine constancy of sporangial and zoospore be-

havior, but also in the interest of finding a method to effect sex organ formation.

Experimental

In pursuing the work, which is here reported, the principles of bacteriological technique were consistently applied. All chances of introducing factors not covered by controls were conscientiously avoided. Where water was used as a medium for growth of the mycelium it was always carefully distilled and sterilized. All chemicals were of high quality and all solutions were accurately prepared. Mycelium, as a source of inoculum, was maintained in stock cultures grown in agar with either corn-meal extract or potato-dextrose as a nutritive base. Inoculations of substrata were made by placing the material, to be used as a nutritive substratum, in contact with a small portion of the mycelium-containing agar, flooded with water, for about twenty four hours. Unless otherwise stated, all clones were developed in Petri dishes which were kept stacked under inverted battery jars during the course of the experiment.

It was first decided to see if cultures originating from different zoospores would all develop and reproduce in a manner answering the description designating the genus Protoachlya. Accordingly, five single spore isolations were made and clones, of these five cultures thus obtained, were all grown under the same conditions. On examination, no differences in the growth and behavior of the clones could be ascertained. It was concluded, in consequence, that, whatever might be the cause of the Protoachlya condition, it was probably not a matter of instability of a single mycelium.

The relationship of the nutritive substratum to the Protoachlya character was sought next. A variety of naturally occurring food substances was chosen. Hemp, orange and tomato seeds, corn, wheat and rice grains, fragments of prune, raisin, orange peel, cocoanut endosperm, carrot and beet root, and also the bodies of ant pupae were inoculated and flooded with a shallow depth of water.

There is no object in reporting the effect of these different substrata on the vegetative development. It is more important, however, to state that the Protoachlya condition remained unaffected. When sporangial development occurred it was essentially similar in all cases. In none of this series of clones

was there any evidence of sexuality. It was obvious that the fundamental generic characters were not dependent upon any one kind of supply of naturally occurring food.

It was thought, if instability of the plant were a factor, that there might be some relation between vegetative vigor and zoospore behavior, of the type concerned. Pieters (1910) has shown a relation between food concentration and mycelial development. Accordingly, a series of clones, employing varying concentrations of a pea extract was arranged. Using as a stock solution a broth prepared by boiling 10 gms. of dried peas for half an hour in half a litre of water, a descending series of 10 per cent increments proved satisfactory for the experiment. Observations made on the clones thus developed were negative in character and no oogonia appeared in any of the mycelia.

For a similar reason, but more especially in the quest of oogonial formations, the procedure was repeated with spinach broth, haemoglobin solutions, leucin solutions and dairy milk dilutions substituted for the pea extract. In all cases good growth was secured, but no information contributing to the discussion was obtained.

Trial had shown that the fungus tolerated a relatively wide range in hydrogen ion concentration, growing just as vigorously at pH 8 as at pH 4. The effect on reproductive activities of varying the acidity of the medium was suggested. Using inoculated hemp seeds as substrata, clone development was attempted in a series of hydrochloric acid solutions ranging from M/75 to M/200 by increments of 25. Except in the M/75 solutions a mycelium was formed in each case. Zoospore formation and discharge occurred, however, only in the lowest concentration. Here the condition was no different from that found in the pure water controls.

In a like manner the effect of potassium hydroxide was tried. The basic nature of the medium was similar in effect to that governed by the hydrochloric acid. No growth took place in the M/75 concentration and no zoospores appeared in any strength exceeding M/200. In neither the acid nor in the alkaline solutions did oogonia occur.

Temperature and light relations were not systematically determined. In the course of over two years the plant had been under observation during a range of temperature varying with climatic conditions. Always the Protoachlya condition per-

sisted. It was of some interest, however, to find that growth practically ceases at temperatures in excess of 34° C. A test on the rate of growth of the mycelium in a solid medium was made by exposing different areas, for forty eight hours, to light passing through standardized red, orange, yellow, blue and green filters. The differences in the wave length seemed to be quite without effect on the mycelium. The effect of light of different qualities, on a developing mycelium growing in an aqueous medium, remains to be determined when suitable equipment for standardizing intensity is available.

A test involving a period of dormancy, while without effect on the Protoachlya condition, is of a little interest. In August 1927 a small quantity of water, containing recently discharged zoospores, was added to tubes of well sterilized white sand and sandy loam. The tubes were then sealed and set aside. Seventeen months later they were opened and the fungus was easily recovered from both sand and soil by adding corn grain fragments and water. Hyphae appeared almost simultaneously on a dozen or more of the pieces of corn material which had been well separated from each other in their arrangement in the dish. The indication was that a number of zoospores were aroused from a dormant condition under the influence of the food diffusion in the water. Clones developed from the mycelium, thus secured, behaved in no way differently from those taken from the initial stock cultures.

As the result of their work, Klebs, Obel (1910) and Kauffman claim a very definite effect of salts on the sexual reproduction of many of the water molds. In earlier phases of endeavor the writer had applied weak concentrations of sodium nitrate and monopotassium phosphate in conjunction with haemoglobin solutions to clones with and without substrata, but with no bearing on sexual reproduction of the organism. A more systematic test, involving twenty five different salts in M/50 and M/100 concentrations, was put into effect. This time, in an effort to minimize the evaporation factor significant when clones are developed in Petri dishes, test tubes with tight fitting cotton plugs were used. Hemp seed embryos, selected for uniformity in size, were inoculated for substrata. These were transferred to the tubes, each of which contained 10 cc of the solutions.

Examinations of the mycelia were made at the end of forty

eight hours, one week and two weeks. It will not be necessary to itemize the apparent effects of the salts in each case. In general it may be stated that those salts that exerted a distinctly lethal effect are:

Strontium nitrate
Cobalt nitrate
Lithium nitrate
Ferric chloride
Ferric nitrate
Uranyl nitrate

Those that either inhibited development or in which spore formation was indefinite are:

Sodium nitrate
Sodium nitrite
Sodium carbonate, normal
Trisodium phosphate
Disodium phosphate
Potassium carbonate
Tripotassium phosphate
Potassium iodide
Magnesium chloride
Magnesium nitrate
Ammonium nitrate
Potassium nitrite

Those in which spore formation was relatively definite are:

Monosodium phosphate
Monopotassium phosphate
Potassium nitrate
Dipotassium phosphate
Potassium bromide
Potassium chloride
Magnesium sulphate

Except in the case of the monopotassium phosphate solution, spore discharge was inhibited in all of the M/50 concentrations. Potassium chloride, in both concentrations, acted strangely on the sporulation processes. Sporangia formation seemed to have been stimulated and the spores were larger than usual. The mature sporangia were suggestive of Thraustotheca, for the wall, due to the bulging of the spores, was scarcely discernible. In general, however, the spores failed to escape either by disintegration of the spore case wall or by way of an apical opening. Germination was invariably *in situ,* as in Aplanes. While this condition occurred in some of the other solutions, more especially in that of potassium nitrate, it was without exception in the potassium chloride clones.

Another feature of the mycelia in the potassium chloride was the appearance of oogonia and antheridia. No credit, however, for this phenomenon may be given to the salt, for the control clones in pure water were also found to exhibit a very positive formation of sexual structures. This provided a new angle for consideration.

Occasionally during the progress of the work various attempts, miscellaneous in character, had been made to induce oogonial development. One particular clone, developed on corn endosperm in pure water for three days and then transferred to a 1 per cent dextrose solution for five days, showed a few well formed oogonia with antheridia applied. The oogonia appeared close to the substratum and were enmeshed in an exceedingly tangled mycelium. Attempts to duplicate the conditions failed to promote further cases of sexuality. Sex structures were also once obtained in a very dense mycelial weft which had been cultivated from about fifteen centers of hemp seed in the one dish. Again the oogonia were found close to the substratum. On a third occasion sex structures were discovered on the mycelium which remained in the dishes containing the soil that had harbored the fungus during its period of dormancy. In this case the clones were nearly three weeks old and an exceedingly dense weft of mycelium had been formed. Further efforts involving the addition of soil to the clones was unsuccessful in respect to sexual expression.

Coker reports that oogonia and antheridia were frequently formed in raw cultures where the water, in which the plant was collected, was maintained. With this in mind the writer obtained some water from the same stream in which the fungus was found and substituted that, after sterilization, for the distilled water which had been habitually used. The effort, however, was without the results desired.

Coker, after many unsuccessful attempts to correlate culture conditions with sexual development of the plant, credited the occurrence of the oogonia as whimsical. This conception had become a deep seated opinion of the writer, but there remained the conviction that the "whimsical" element could eventually be dispelled. The occurrence of sex organs in the controls of the salt series provided a suggestion for a fresh endeavor.

A series of clones, on hemp seed, was developed in tubes of water of varying depths: 0.7, 1.3, 2.6, 4.7, 5.9, 7.3, 8.9, and 10.3 centimeters were the heights of the columns of water. After five days the clones were examined and oogonia were found on all of the mycelia which had been submerged in a depth of water 4.7 centimeters or more. At a later date, sex organs appeared in one of the tubes of the 2.6 category, but

on the clones in all of the shallow water tubes no fructification was found. The writer had no difficulty in successfully duplicating the experiment and has since been able to secure oogonial production at will.

Simple and reliable as this method of inducing sexual manifestation seems to be, it is nevertheless empirical and an explanation was accordingly attempted.

Apparently there were but two differences between the shallow and the deep water conditions. In the shallow water the dilution action of the water on the metabolic products was small. Also, the mycelium was less removed from the air and consequently from an inexhaustible supply of oxygen.

If waste products from the fungus interfered with the formation of oogonia, then sex structures should never have appeared on the clones developed in Petri dishes where the amount of water was small and the amount of mycelium large. Furthermore, in a large number of cultures under observation for fructification, the mycelium had been kept washed out with fresh water, but the removal of waste matter by this means had not yielded desired results. Presumably the subject of metabolic products was not involved, at least directly.

If oogonial formation required anaerobic conditions, then the appearance of sex organs, infrequent as it was, should not have occurred on the clones developed in Petri dishes. However, this contradiction is not entirely genuine. It will be recalled that sex organs which occurred in the flat dishes were formed near the substrata and always were found enmeshed in a dense weft of mycelium. The density of this mat might well have provided anaerobic conditions, wholly or partially for that part of the thallus from which the oogonia originated. Hypothetical as such an explanation may be, it was accepted tentatively by the writer and more information on the relation of the fungus to anaerobic conditions was sought.

While the writer has frequently seen saprolegniaceous growths several feet below the surface in aquaria and has, on some occasions, observed the white mycelium in spring water well beyond an arm's reach, he had never though to question the aerobic habit of these fungi. It would have been assumed, and perhaps correctly so, that the amount of dissolved oxygen in the water was sufficient to dispel any idea that the organism might have the ability to exist as a facultative anaerobe. To

gain further information on this matter a series of tubes was arranged with the fungus inoculum placed midway in a column of solid culture medium, potato-dextrose agar. To effect this, the agar medium was added to the tubes to a height of three centimeters. After solidification, a small portion of mycelium containing agar was introduced into the tube and placed on the hardened surface of the medium. Care was exercised to avoid touching the sides of the tube with the mycelium. A few drops of cooled, but still liquid, medium were added to hold the inoculum in place when solidification occurred. Further medium, in a similar state was added until the level stood at six centimeters from the bottom of the tube. The tubes were then set aside for four days.

At the end of that time the agar columns were removed by breaking the bottoms of the tubes to avoid air pressure interference. Longitudinal sections were then made of the columns of the medium and examined. In each case it was found that the hyphae extended towards the bottom of the tube for a distance not exceeding six to seven millimeters. By a few rather delicate strands, however, the mycelium reached the surface and there, by a multiplicity of branching it had formed a weft.

As the tubes of this series had been kept upright in a rack during this experiment, the possibility of geotropism had not been taken into consideration. To offset this objection, a similar series of tubes was so arranged that some of the columns were inverted, in respect to the upper surface, others were placed horizontally, and the controls kept as before. The results were all the same. The mycelium grew towards the closed end of the tube for a short distance, but it never failed to reach the surface in the other direction. (See figure 1.)

To vary the experiment and to neutralize the effect of gravity, a pair of columns, inoculated in a similar manner, was equipped so that it could be rotated on a two-tube centrifuge. After spinning these columns at a little better than thirteen hundred revolutions per minute for forty eight hours, the direction of growth was ascertained. As far as the behavior of the mycelium was concerned there was no evidence of any effect from the rotation.

To explain how the hyphae found their way towards the surface was a matter of conjecture. It was assumed, that, since the agar surface was in contact with the air, the concentration

of dissolved oxygen was greatest at the top and became less and less as the bottom was approached. To avoid this situation, yet another series of inoculated columns was prepared and, as soon as the top layer of agar had hardened, molten paraffin was added to a depth of about one centimeter. This would minimize the difference between the concentration of dissolved oxygen in the upper layer and that of the lower. Results were anxiously awaited.

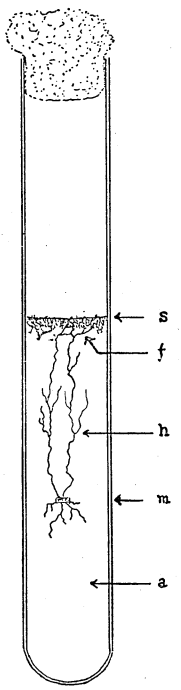


FIG. 1

s—surface of medium
f—fungus weft
h—fungus hyphae
m—inoculum
a—nutritive medium, agar

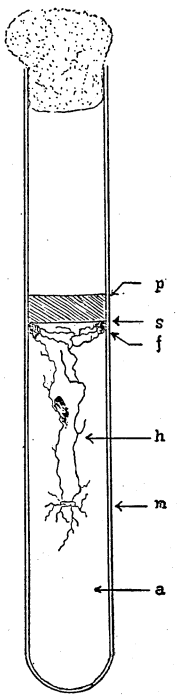


FIG. 2

p—paraffin seal
s—surface of medium
f—fungus weft
h—fungus hyphae
m—inoculum
a—nutritive medium, agar

Examination showed that the hyphae had penetrated to a distance of seven millimeters from the starting point towards the closed end and had extended the full three centimeters towards the paraffin. On approaching this surface they could

be seen traversing horizontally in the agar and branching richly where they reached the point of contact between the paraffin and the sides of the tube. (See figure 2.)

There is but one explanation in order. The mycelium of this fungus must be able to develop in a medium very nearly, if not entirely, free from uncombined oxygen. Furthermore, it is evidently able to respond to minute variations in the concentration of free oxygen.

Quantitative data are yet to be obtained on oxygen relations, not only in respect to growth, but especially to the reproductive functions. The writer is at present engaged in pursuing this problem and hopes to eventually have something of interest to report.

In the process of preparing this paper the writer has attempted to include the essentials of a discussion along with the report on each phase of experimentation. It only remains to be said that the fungus under consideration has persisted in exhibiting very definite characters under the conditions to which it has been subjected. And since these characters are quite in accord with those described by Coker for his Protoachlya paradoxa, when grown under conditions similar to those used by the writer for controls, it is assumed that our plant and those of Coker were individuals of the species. Unless contrary evidence, based upon offspring from a fertilized egg, is brought to light, the writer feels content to regard the genus Protoachlya as a distinct entity.

Summary and Conclusion

1. The investigation has attempted to show that an individual fungus, answering the description of Protoachlya paradoxa, is physiologically stable. It is therefore not to be regarded as a temporarily aberrant form of either Saprolegnia or Achlya.

2. Due to sex organ appearance, with but few exceptions, only when well out of contact with the air, it is assumed that sexual expression bears some relation to free oxygen.

3. The fungus is able to develop under anaerobic conditions, but has a preference for conditions approaching the aerobic.

4. This is the first appearance of the species in Wisconsin, in which region it is probably rare.

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PHYSIOLOGICAL STUDIES IN RELATION TO THE TAXONOMY OF MONASCUS SPP.

ELAINE M. YOUNG

A sporadic and destructive development of "mold" in the kilns of a maize starch factory, near Johannesburg, South Africa, in 1926, aroused sufficient interest to warrant an inquiry into the physiological characteristics of the fungus. The rich pink coloration of the starchy substratum and the microscopic appearance of the mycelium, led to its identification as a species of Monascus. Considerable assistance was given, in this connection, by Dr. Johanna Westerdijk and Miss Mes of the Bureau voor Schimmelkultuur, Baarn, Holland, to whom the writer is indebted not only for suggestions, but for cultures of related species. It was not then possible to come to any satisfactory conclusion about the specific name of the form, with the result that further work was carried out in the University of Wisconsin, as a subsidiary problem to a more detailed cytological study, the results of which will be published in a subsequent paper.

The genus was first described in 1884, by van Tieghem (20), from material on a boiled potato culture in France. At this time he determined two species: *M. ruber,* the type form, and *M. mucoroides,* with somewhat larger fruiting structures. Another species, erroneously regarded as *Physomyces heterosporus,* found by Harz (9) in glycerin solutions in a soap factory in Bavaria, was later correctly determined by Schröter. In 1895, Went described *Monascus purpureus,* which he obtained in Java, where, however, it was not originally grown. The Chinese cultivate the fungus on rice, with the result that the mycelium develops profusely until the rich crimson pigment has permeated the grains completely, when the whole mass is dried, cut into cakes, or ground to a greyish red powder. In this form it is exported throughout Eastern Asia, where it is known under the trade names Ang-quac, Ang-khak, Beni-koji and Aga-koji, and used extensively in the coloring of fish and other foods and in the preparation of spirits. This species

and the closely related *Monascus Barkeri* Dangeard are of additional commercial importance in the manufacture of Anchu and Samsu, alcoholic drinks. From Saito's description it seems clear that Beni-koji is in reality composed of *Monascus purpureus* and a yeast, the former being capable of breaking down the rice starch into a simple sugar, while the yeast renders the further conversion into alcohol possible. The whole process, then, is effected by these two distinct organisms.

Went (22) first attempted an investigation of *Monascus purpureus,* both from the morphological and from the taxonomic point of view. He considered the fungus as belonging to the Hemiasci, in accordance with the views of van Tieghem and Brefeld, and his conclusions were supported in the main by Uyeda, working later with the same organism. It was Barker (1), however, a few years later, who secured material of the Samsu fungus from the Malay Peninsula; he made a careful cytological study of all stages in the life history, and established its identity as a true Ascomycete, although he regarded it as a very simple sexual type. Ikeno (11) and later Kuyper (13), working with the same species, strenuously opposed Barker's views, the former continuing to regard the fungus as a Hemiascomycete, while the latter proposed to establish a new order, the Endascineae, for this genus, and to include it among the true Ascomycetes. Olive (16), supports Barker to some extent, but disagrees in regard to the perithecial initial; he feels convinced, however, that all the previous authors have been dealing with *Monascus purpureus* which seems justifiable, since all the material came from pigmented rice. Dangeard (6) regards the Samsu fungus as a distinct species without, however, giving any description of its individual peculiarities. Barker had found certain morphological and cultural differences between his form and *M. purpureus,* but he stresses the probability that Went was dealing with a fungus having a less specialized fruiting body. This explanation based on the wide divergency in interpretation of perithecial development by these two authors must be ignored in the light of Schikorra's studies on *M. purpureus* Went, which will be considered below. In any case, the morphological characters, upon which species are largely based, would make *M. purpureus* and the Samsu fungus closely related species. A summary of the distinguishing features of *Monascus Barkeri,* will be given later.

In 1909 appeared the valuable cytological contribution to the life history of Monascus by Schikorra (19). Besides the investigation of *Monascus purpureus* Went, a comparison was made with another, "non-pigment"-producing, form from a fermentation institute (Gärungsgewerbe) in Berlin. From his observations, and also from recent cultural studies, it seems probable that Schikorra's *Monascus X* is a distinct species.

Reports of Monascus occurring in an unusual environment came from America in 1910, the first by Buchanan (4) from material causing mold in maize silage, the second from a bottle of pickles isolated by Lewis (15) and identified by him as *Monascus Barkeri* Dangeard. In the same year Piedallu (17) records a number of culture trials carried out in order to ascertain whether a form, which he collected from oil cans and skins from a tannery in France, was *Monascus purpureus,* as he had suggested in a former paper. After a comparison with Went's species and with *Monascus Barkeri* Dangeard on various media, he concluded that his fungus differed from them chiefly in physiological characteristics, and referred it to a new species, *Monascus olei* Piedallu.

Since that time there have been no published reports of any further species, although in correspondence with Dr. Leva Walker of the University of Nebraska, it appears that the fungus, although somewhat sporadic, is fairly common on maize silage in the corn belt. Some herbarium material of moldy silage, several years old, kindly sent by her, has since been kept in cultivation in a flourishing condition.

It is evident that Monascus is a cosmopolitan genus, for its range has been extended not only to South Africa, as stated above, but an unpublished record by Charles McGee of two strains on maize silage was made in Australia in 1926. To him acknowledgments are due for material of these strains grown on silage agar. In any consideration of this extended range, it will be necessary to take into account the fact that various agronomic strains of maize have been exported from America to South Africa and Australia during the last two decades, and that contaminants must obviously have been carried along with the grain.

I. The Maize Starch Mold

An inspection of the factory from which the moldy starch blocks came led at first to the impression that the dampness and the supply of carbohydrate and proteinaceous materials contained in wooden troughs were admirably suited to the growth of Monascus. In all sections of the building, however, where the germ is freed from the rest of the grain, and through the shaking and settling processes, the starch is in motion in SO_2 water (0.02 to 0.06% concentration). Only along the sides of the troughs, where splashing occurs, and on the sacking around the iron posts, were there evidences of pale pink masses of *Fusarium* sp. accompanied by a bacterial growth. In no case could Monascus be identified in these masses, in spite of repeated examination. As the starch settled and the gluten was diverted to another channel, the excess water was drained away and the mass was cut into blocks which were subjected to a blast of hot air at 96° C. in wooden-lined kilns. Any impurities (chiefly mineral) were then cut away with the outer crust, and the blocks were wrapped in heavy kraft paper. Up to this stage there was no opportunity for the development of mycelium, but here the blocks were placed in steam-heated kilns where the temperature rose slowly from 43° to 66° C., during a period of 14 days. The infected blocks were located in that part of the kiln which was farthest from the pipes, indicating some heat irregularity such that in regions where a temperature between 30° and 40° C. prevailed, an ideal environment was provided for the germination and development of the fungus.

In the kiln the remarkable development of the mycelium had prevented the normal "crystallizing" process; the starch dried out very slowly and became divided into prisms, so that the product was valueless, being loosely granular, and colored at intervals throughout by a delicate rose pink and spotted by innumerable perithecia. The individual starch grains were swollen and often burst, the ramifying hyphae very much contorted (fig. 1). The presence of a certain amount of glucose as a result of the fungal activity, along with the mechanical binding action of mycelium, held the block together.

Much of the waste starch lying in the region of the kilns, contained vigorous growths of *Penicillium* sp. and *Aspergillus*

sp., but no consideration was given to these, since better factory sanitation would prevent their serious development.

Physiological Studies

After attempting to isolate the fungus directly from the block, it was found that far cleaner cultures were obtained if the moldy starch was washed overnight in running water. The individual perithecia could then be separated on a sterile glass slide in sterile distilled water, and broken inside the tube of agar before the plates were poured. The most successful nutrient medium was made by mixing 40 gms. of crushed maize seedlings with 600 cc. distilled water. This was used either as a nutrient solution, or combined with 12 gms. of agar as a solid substratum. Growth of the fungus is most rapid at 30, 35, and 40° C., although limited at the higher temperatures by the agar drying out very rapidly; cultures below 30° are slightly slower in development, and, below room temperature, considerably delayed. The lower temperature limit for growth was not determined. Conidia are produced after 16 hours and perithecial development is initiated within 48 hours. A deep crimson pigment appears within a week, increasing rapidly in older cultures. On darker media a purple tint appears in the red pigment, but rice cultures remain a vivid crimson. The pigment, however, fades fairly rapidly in the light, for freshly broken infected starch blocks, showing a rich pink interior, bleach out completely after some exposure. The mycelium is at first white, becoming gray in older parts in consequence of the prolific development of perithecia, which tend to appear in definite zones that are particularly marked on maltose agar.

In the nutrient solution growth is somewhat slower, but a spherical clump gradually appears in the liquid, which later turns crimson. Microscopic examination of this submerged mycelium reveals straight, vigorous, vacuolated hyphae, producing conidia rarely, and then singly at the tips of branches. This character is illustrated in figure 8; a portion of the mycelium having rich protoplasmic contents, numerous vacuoles, and almost no oil globules is shown in 8*a*; the formation of a single conidium in 8*b*; and a swelling, not completed as a conidium, but later extended to form two projections which will develop branches, in 8*c*. After some time, when the amount

of nutrient in the tube is reduced by half on account of evaporation, a portion of the mycelium develops on the surface, producing perithecia in that region, but not in the interior. Later work on the material of Monascus from Australia showed that similar vegetative growth occurs in 5% glycerin, until, when the liquid has evaporated considerably, perithecia are initiated all through the medium as well as on the surface. It seems evident, therefore, that there is a correlation between concentration of nutrient solution and perithecial formation, in accordance with the results obtained by Klebs (12) with oogonial development in a strain of Saprolegnia, and to some extent with those of Coons (5) on pycnidial development in *Plenodomus fuscomaculans* Sacc.

Humidity

The somewhat rapid change in humidity in all these cultures under such warm conditions, as well as in the kilns, is suggested as a factor in the early formation of perithecia. On agar slants the growth is decidedly superficial at first, but later the mycelium develops toward the interior of the agar, this imbedded habit apparently being in response to the drying out under aerial conditions.

Effect of Protein Percentage

Several preliminary chemical analyses of moldy starch were made by Mr. J. A. McLachlan, the chemist associated with the factory, in order to ascertain whether the amount of protein present bore any relationship to fungal growth. The writer is gratefully indebted to him for these, as well as for the glucose determinations, for information concerning the technical aspects of starch production and for many helpful suggestions. His results showed that infected starch contained more than the minimum amount of protein, occasionally as much as 0.67%. Artificial cultures, in this connection showed the following:

(i) peptone agar—growth fairly good. Very slight pigmentation evidently associated with carbohydrate impurities in the commercial preparation.

(ii) pure gluten agar—growth poor, no pigmentation.

(iii) pure crystal starch agar—growth slight, clear rose-pink pigmentation.

(iv) coarse corn meal agar—growth good, red pigmentation.

No cultures having varying proportions of protein combined with carbohydrates were attempted, but cultural characters here and on maize seedling extract agar, as contrasted with pure starch agar, pointed to the beneficial effect of the presence of some protein. Further support of a proteinous medium playing some part was given in a second paper by Saito (18) on the enzymes of *Monascus purpureus,* where he showed that this fungus secretes a protein splitting enzyme, but no invertase.

Temperature and Oxygen Supply

The fungus was shown to develop under a wide range of temperature conditions, and although the reading at the commencement of the last kiln process was 43° C., the following statements by McLachlan are of interest:

"The present design of the crystal kilns is such that uniform conditions of temperature and humidity are practically impossible, and this factor alone could account for the presence of mold in certain portions of a charge and not in others." The conidial and ascosporic inoculum, evidently from infected grain, is present throughout, and resists the period of subjection to hot air at 96° C. The fungus finds ideal conditions for germination in parts of the kiln where the temperature is slightly lower than 43° and an abundant supply of food material is provided.

No attempts were made to ascertain whether oxygen supply bore any relation to perithecial formation, as was suggested for *Monascus purpureus* by Went, although his experiments in that direction were not successful.

Acidity

With regard to the question as to whether the acidified water, which in the later processes reached a concentration of 0.1%, was efficacious as an inhibiting factor in the production of mycelium, several cultures were attempted. The fungus showed considerable tolerance to acidified liquid media and better growth on slants to which 1 to 5 drops of 1% SO_2 were added. Germination of ascospores took place in 0.025% SO_2 water, while conidia germinated in a 0.1% solution, but not in 0.15% SO_2 water.

Under factory conditions, then, control of the mold was ef-

fected most satisfactorily by increasing the acidity of the SO_2 water used in the various processes.

Systematic Position of the Fungus

(a) *Description.* Mycelium from starch block contorted; in artificial culture, usually straight, hyphae 4μ, rarely 3 to 5μ in width, colorless, considerably branched in a monopodial or pseudo-dichotomous manner; conidia ovoid to pyriform varying considerably in size from 6 x 5μ to 16 x 14μ. (It may be noted that the length is given first in all cases.) Walls colorless or with a fair reddish light brown tinge; perithecia spherical 25 to 55μ in diameter, or subspherical 37 x 36μ to 50 x 42μ, walls colorless to light red brown; ascospores ellipsoidal 5 x 4μ to 6.5 x 4μ colorless, walls highly refractive. *Habit:* impure maize starch.

Growth on a variety of artificial media is easily obtained, but is luxuriant on potato-beef extract, dextrose agar, and corn-seedling extract agar (with 1 to 5 drops lactic acid added to each 5 cc. of medium). Pigmentation ranges from delicate pink in starch block, crimson on dextrose, dextrin and maltose agars, to deeper red, with slight purple tinge on dark colored media. Microscopic examination of milk culture shows presence of two distinct pigments, yellow and red, the latter predominating, but the yellow easily soluble in water. Range in temperature conditions considerable, optimum between 30 and 35° C., much delayed at 19° C., no growth beyond 45° C.; in acid conditions, growth fair in 1% lactic acid, and SO_2 water up to 0.1% concentration.

(b) *Discussion.* According to the description, this species conforms most closely to *Monascus ruber* van Tieghem. There are, however, certain diverging characters: i. e., ascospores not more than 6.5 x 4μ, perithecia not strikingly red. A culture of *Monascus ruber* van Tieghem was obtained from the Bureau voor Schimmelkultuur, Baarn, Holland, labelled as such, but this fungus is almost identical with the starch mold, in particular, the ascospores are 5 to 6.5 x 4μ; the perithecia although usually red to red-brown, are often colorless; the range in size of conidia includes the measurements given by van Tieghem. If this specimen from Holland is exactly like the type form, then the size of the ascospores must have been exaggerated by

van Tieghem; on the other hand, it may be from a later collection, and identified as *Monascus ruber*. However, it seems evident that an authentic specimen of van Tieghem's type material does not exist. Although in culture the hyphae, conidia and even ascospores, to a slight extent, vary in size, the latter are approximately stable. Taking into consideration the deviation in size of ascospores and lack of any clearly defined red in the wall of the perithecium, in comparison with van Tieghem's fungus, there seems no justification for creating a new species for the starch mold which will be designated as *Monascus ruber* van Tieghem.

II. Maize Silage Molds

The two cultures of Monascus, mentioned earlier as having been sent from Australia, have shown consistent differences. The specimen from South Coast (sample E) forms a more vigorous mycelium which changes rapidly from a white cottony growth to dark grey, at 25°–35° C., in contrast to the Glen Innes material (sample F) where the growth is less conspicuous, paler, taking on a tinge of light brown as it ages. The morphological characters of both coincide with the starch mold, so that they are, therefore, specimens of *Monascus ruber* van Tieghem. The characteristic appearance of E is due to the excessive production of fruiting bodies whose walls range from colorless to light yellowish brown, but the interior is more often red, particularly in milk cultures. These perithecia vary considerably in size, spherical from 32 to 50μ in diameter or subspherical 32 x 30μ to 68 x 64μ; they are completely filled, in most cases, by ascospores whose colorless walls, by their highly refractive property, are largely responsible for the grey coloration. In culture and mycelial characters, F corresponds entirely with the specimen of *Monascus ruber* from Europe. Both fungi produce the vivid crimson pigment, without such definite additional yellow coloration appearing as in the starch mold. It may seem that pigmentation is stressed unduly, but these forms can readily be distinguished by this character. As an additional observation, the silage mold (sample G) from Nebraska always possesses a brown coloration, which gradually permeates the grey mycelium covering the strongly reddened nutritive medium, particularly in older cultures.

In consideration of the above statements, it is evident that the starch fungus and the silage molds, E, F, G, are separate strains of *Monascus ruber* van Tieghem, differing from one another biologically. The organism from silage, studied by Buchanan in 1910, is probably another strain of this somewhat variable species, for, although he suggests that it is *Monascus purpureus* Went, cultural characters of this latter fungus, combined with the nature of its conidia and ascospores, distinguish it from the silage molds. As in the case of the starch fungus, germination of conidia in strain E occurs in 6 hours. In figure 3 the germ tubes are shown issuing from a part in the spore wall, away from the region of attachment to the hyphal end. The cytoplasm is granular, rich in oil, and filled with small vacuoles. During the following 12 hours, septa are laid down in the elongating hypha, from which branches are beginning to develop, while conidia are formed in the older part (fig. 4). In cultures 48 hours old, particularly those grown at 35° C., conidia are present in abundance, often in long chains, which may be interrupted by short, unthickened portions of the hyphae, as in figure 5. When the fungus is cultivated on beef extract dextrose agar, a considerable development of chlamydospores results, although these may be found to occur upon other media to a slight extent. Portions of the hypha are separated by septa and, without any preliminary swelling, become thick-walled chlamydospores. These may break away as do the conidia, but have not been seen germinating (fig. 6). Many of the perithecia in such cultures are small and contain only two asci (fig. 7).

Degeneration in Stock Cultures

Particular interest has been centered in strain E of *Monascus ruber,* because its prolific perithecial development renders it admirably suitable for cytological study. Difficulty in arriving at the systematic position discussed above resulted in various attempts being made to secure Monascus cultures from Eastern Asia, but without success. It was necessary, then, to use transfers of *M. Barkeri* Dangeard, *M. Purpureus* Went and Schikorra's form from the stock cultures kept at Baarn, Holland. All these, however, showed obvious signs of degeneracy, evidenced by complete lack of perithecia, irregular, desultory

conidial production and hyphae with disintegrating contents. This condition has been brought about by accumulation of toxic products in the cultures, resulting from a slight bacterial contamination occurring persistently in rice flasks. It is clear that the rice used was not sterilized, either by thorough autoclaving, nor by discontinuous sterilization for three successive days. This has caused considerable trouble in the culture work, and has necessitated the various known purifying methods being used.

In order to be quite sure of dealing with pure cultures, acid agars and solutions have been tried, since considerable acid toleration was shown by the starch mold, and as suggested by Brown (3) and also Hopkins (10). *Monascus purpureus* develops successfully on agar in which 1 or 2 drops of lactic acid have been added to each 5 cc. of the medium. When, however, 5 drops are added, growth practically ceases and the hyphae become bright yellow and filled with oil globules. There is no development in a 1% solution of lactic acid. This species forms conspicuous coils of hyphae on agars particularly those poor in food materials (fig. 2). These coils occur less frequently in silage molds. *Monascus X* Schikorra continues to develop a mycelium on ordinary media, but still without any fruiting bodies. It grows sparsely in 1% lactic acid, but well in 5% glycerin to which 1 drop of lactic acid has been added.

Monascus Barkeri Dangeard which in all solid cultures shows no signs of pigmentation, grows in 1% solution of lactic acid, also in acidified glycerin, where a delicate violet purple coloration has been observed. Only hyphae varying somewhat in width bearing infrequent single apical conidia are produced.

After the acid treatment, *Monascus purpureus,* when grown on potato dextrose agar, forms perithecia, so that it has been possible to compare this fungus both culturally and morphologically with the molds already discussed. Such satisfactory restorative vigor has not as yet been shown by either *Monascus Barkeri* or *Monascus X* Schikorra, so that it is impossible as yet to state with certainty whether this latter form can be raised to specific rank.

In order to determine the limit of acid toleration shown by strain E of *Monascus ruber,* a series of acidified distilled water ($\pm$ pH 6) cultures of varying acidity were used. Conductivity water (pH 6) acted to some extent as a check and also served

to illustrate the minute quantity of food materials required by the fungus for the development of perithecia. Lactic acid solutions ranging from 0.05% increasing by intervals of 0.05% in the first case, and 0.5% in the remaining nine, were made up in sets—each set consisting of six tubes. The individual tubes contained 5 cc. of liquid. The cultures were placed in the incubator at 29° C.

The observations made during the succeeding period of four weeks are recorded in the following table.

Medium	Extent of mycelium	Pigmentation	Perithecia	Microscopic characters
Lactic acid. Percentage: 0.05	1/8-1/4 in. wide	Slight pink coloration in grey mycelium, liquid uncolored.	++	Hyphae filled with oil; perithecia and conidia numerous, light colored.
0.1	-1/4 in. wide	Rich pink coloration in grey mycelium mass, liquid uncolored.	++	Hyphae filled with oil; conidia and perithecia numerous, brown.
0.5	-1/2 in. wide	Rich pink to red; liquid bright yellow	+	Hyphae filled with oil, walls slightly brown, conidia few, signly or in chains of 2. Perithecia rare.
1	1/2 in. wide	Rich pink to red; liquid bright yellow	+	Hyphae filled with oil, walls slightly brown, conidia few, singly or in chains of 2. Perithecia rare.
1.5	1/2 in.	Rich pink to red, liquid bright yellow	—	Hyphae similar, conidia few, no perithecia
2.	1/4 in. wide	Rich pink to red, liquid bright yellow	—	At first hyphae richly vacuolate, with few oil globules, Conidia rare, single, distorted. Older cultures rich in oil, hyphal walls red brown, irregular contorted short branches. No perithecia.
2.5	1/2 x 1/4 in.	,,	—	,,
3.	,,	,,	—	,,
3.5	,,	,,	—	Hyphae rich in oil, numerous irregular short branches. No. traces of conidia or perithecia.
4.	Slight, considerably delayed growth	,,	—	,
4.5	None		—	
Conductivity water pH 6	1/8 in. wide	Grey coloration of the mycelium. No red visible, liquid uncolored	++	A small amount of mycelium with numer- conidia and perithecia.

Just as in the case of the starch mold, strain E shows a pronounced tolerance to acids. Transfers made from 3.5% lactic acid cultures on ordinary agars have provided the stock mate-

rial for microscopic work, since the fungus is now pure. Fresh mounts of this growth still continue to have minute bodies in the field within conidia and hyphae, exhibiting rapid Brownian movement. Staining with Sudan III shows them up as oil globules. These are evidently the bodies noted by Piedallu in his reference to minute bacilli in symbiosis with the fungus. Perithecia evidently develop in media varying considerably in amount of nutritive material. There is not only sufficient food supply in 0.1% lactic acid, but in conductivity water to produce fruiting bodies filled with normal ascospores. Although in acid solutions there is a limit to the concentration the fungus will tolerate, a vigorous growth is maintained in a considerable series of sugar solutions. For example, in maltose solutions, mycelium and fruiting bodies are found in concentrations ranging from 0.25 to 15%. In the higher dilutions there is no accompanying red coloration, but it appears and increases in intensity with the concentration of the medium; grey streaks all through the diffuse mycelial mass are the zones of perithecia. Extent of mycelial development increases with the concentration, but no cultures above 15% were tried in order to ascertain the extent to which this will occur. The optimum solution for perithecial development appears to be 2.5%.

A tendency towards degenerate types of growth in solutions of greater acidity is displayed by the mycelium, which is remarkably like that found in the stock cultures of *M. Purpureus* Went, *M. Barkeri* Dangeard and *Monascus X* Schikorra. The last three species are far less tolerant to acids than *Monascus ruber,* but in each case a growth occurs in media containing a certain concentration of a weak acid, but, when the quantity of dissociated H-ions is increased beyond the capacity of the individual fungus, a degenerate type of development results. This increase in H-ion concentration may be obtained by using a more concentrated acid solution, or may be derived, after a time, from the staling products of the fungus itself. The extremely slow growth of the bacterial contamination in some stock rice cultures points to the probability that the accumulation of excess acid, as a staling product from the mycelium, is an important factor in slowing up the further development of the fungus itself and also provides an environment too unfavorable for bacterial activity. It is well known that the production of staling substances is evidenced by a characteristic zona-

tion of the mycelium. This is strikingly shown in Monascus, where regular bands are sharply delimited by the presence of numerous perithecia. If Monascus spp. are kept in culture it is necessary to make transfers at reasonably frequent intervals, sometimes to a different substratum, but in the writer's experience material which can be kept in a dried form is far more satisfactory, an interesting case being that of *Monascus purpureus* which is handled commercially by the Chinese in the dried cake or powder form, where the ascospores remain viable for an indefinite period and are unaffected even when arsenic is added as a preservative.

Conclusion

Cultural studies of Monascus spp. have been of considerable value in the recognition of specific forms which are closely related. Of these, the silage and starch molds have shown some interesting physiological characters sufficiently distinct to warrant their being regarded as various strains of a single species, *Monascus ruber* van Tieghem, a description of which has already been given.

Monascus purpureus is characterized particularly by having ascospores which are usually spherical, being 5μ in diameter, or slightly ovoid, their size being 6 x 5μ. The youngest part of the mycelium is white, but it rapidly changes to a rich pink and later to a distinctly orange yellow, presumably as the environment becomes more acid, since this species is less tolerant to acids than *Monascus ruber,* and in an acid medium produces bright yellow hyphae. The pigment found in the substratum as the culture ages is deep crimson. Conidial production is infrequent.

Monascus Barkeri differs from *M. purpureus* in its prolific development of conidia, usually in chains, while the ascospores are ovoid, measuring 8 x 4μ. Although the present culture has shown no fruiting bodies, the cultural characters are distinct. A clear violet coloration appears in liquid media and the optimum temperature for growth is 25° C., (no development beyond 30° C.).

Monascus X is characterized by producing a vigorous pure white mycelium and, according to Schikorra, having larger ascospores than *M. purpureus.* No pigment is produced, ex-

cept in a few instances where a slight pink tinge may occasionally be discerned. Nothing further can be stated in regard to morphological characters since the culture is not fruiting, so that the question of whether this fungus is a distinct species must be deferred.

Monascus olei differs from the two previous species in physiological characters. These, alone, seem to provide insufficient grounds for the creation of a new species, but Piedallu appears to have made careful comparative studies before coming to any conclusion. His diagnosis must be accepted at this time, since it has not been possible to obtain cultures of the form.

Monascus mucoroides is also not available, but from van Tieghem's description, it is clearly a distinct species, characterized by the lack of pigmentation and the size of conidia, perithecia, and ascospores.

Lastly, it has not been possible to procure a specimen of *Monascus heterosporus* (Harz) Schröter, but in consideration of the pronounced variation in shape and size of conidia in *M. ruber,* there seems to be no justification for regarding the Harz form as a distinct species. This modification was suggested by Lafar in his description of this fungus, which is here definitely incorporated with *Monascus ruber* van Tieghem.

Summary

1. A strain of *Monascus ruber* van Tieghem causing moldy starch in South Africa, two strains from maize in Australia, and one from a similar environment in Nebraska, are reported.

2. The activities of the starch fungus cause, under certain conditions, the destruction of entire starch blocks. Luxuriant development occurs between 30 and 35° C., some growth at 40° C., but none at 45° C. A considerable growth occurs in 1% lactic acid and perithecial formation occurs in SO_2 water up to 0.1% concentration.

3. The temperature at which drying of the starch blocks is begun and the naturally rapid development of the fungus contribute to these sporadic and widespread occurrences, but the main factors are seen to be associated with the great tolerance of the fungus to acids and the vigorous growth in starch containing an excessive proportion of protein.

4. Of the silage molds strain E develops perithecia in greatest quantity; this fungus shows considerable acid toleration, forming a mycelial growth in 3.5% lactic acid. Perithecia are produced on a variety of media, particularly those containing carbohydrates, but fruiting also occurs in 0.1% lactic acid and conductivity water.

5. The various species of Monascus degenerate after continued growth on artificial media, while dried material retains its vigor over a period of years.

6. Up to the present there appear to be five clearly defined species in this genus: *M. purpureus* Went, *M. Barkeri* Dangeard, *M. olei* Piedallu, *M. mucoroides*, and *M. ruber* van Tieghem.

7. *Monascus heterosporus* (Harz) Schröter) has been incorporated with *Monascus ruber*, which is a variable species, as shown by cultural studies, and includes a number of strains.

8. It will be necessary to obtain fruiting cultures of *Monascus X* Schikorra before it can be ascertained whether this is a distinct species.

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Explanation of Plates

All drawings were made with the aid of a camera lucida, from fresh material.

Plate 3

Fig. 1. *Monascus ruber,* as present in maize starch block, showing contorted mycelium, and broken perithecium, liberating ascospores. × 1280 (approx.).

Fig. 2. Hyphal coil from culture of *Monascus purpureus.* × 736.

Fig. 3. Germinating conidia, showing germ tubes, and flattened region of attachment to hypha. × 1175.

Fig. 4. A culture 18 hours old, showing stages in development of branches at (a) and (b); the remainder of the original conidial wall is heavily outlined.

Plate 4

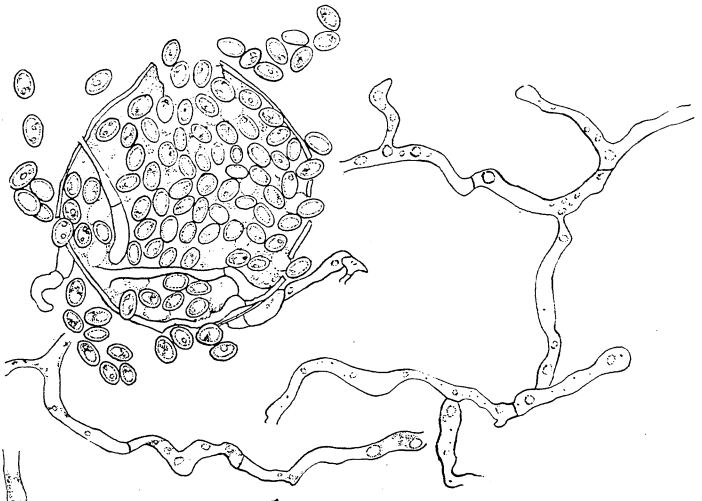
Fig. 5. Portion of a mycelium in a culture 48 hours old, showing formation of conidia in chains of varying lengths.

Fig. 6. Chlamydospore production characteristically produced in the mycelium on beef extract-dextrose agar.

Fig. 7. A portion of the mycelium from the same agar culture, showing a small perithecium, with the trichogyne projecting downwards and the antheridium lying partly at the back, but extended into a branch bearing two conidia.

Fig. 8. A portion of the mycelium developed in dilute nutrient solution, showing at (a) rich vacuolate cytoplasm with no oil globules; at (b) a young conidium, and at (c) a swelling, which may have formed a conidium, but which has extended to form a branch, the apex of which is dividing pseudo-dichotomously.

(Figs. 3–8 inclusive are taken from strain E of *Monascus ruber,* and have a magnification of × 736).



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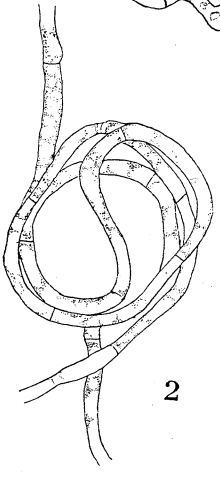

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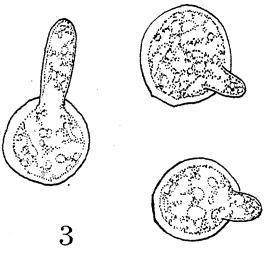

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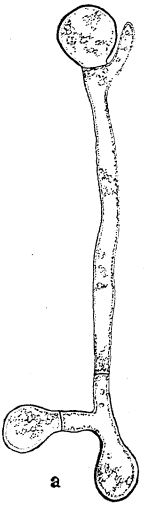

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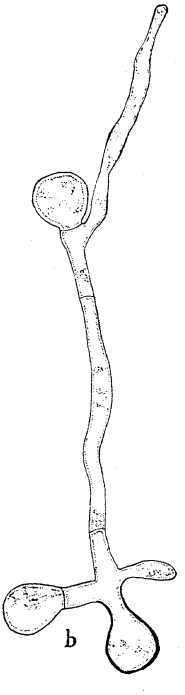

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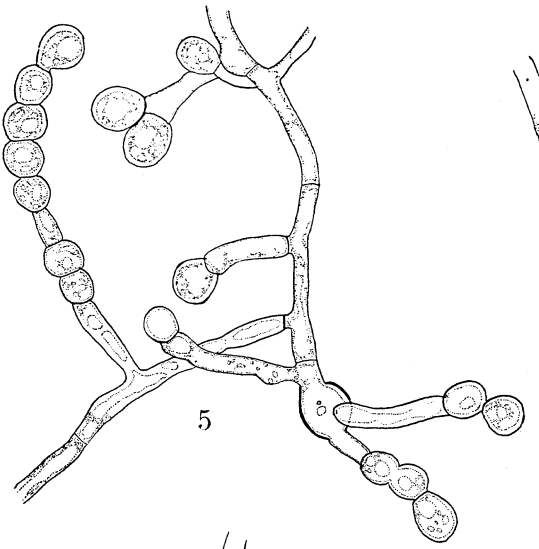

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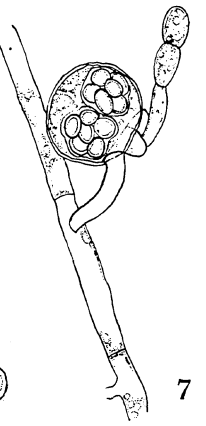

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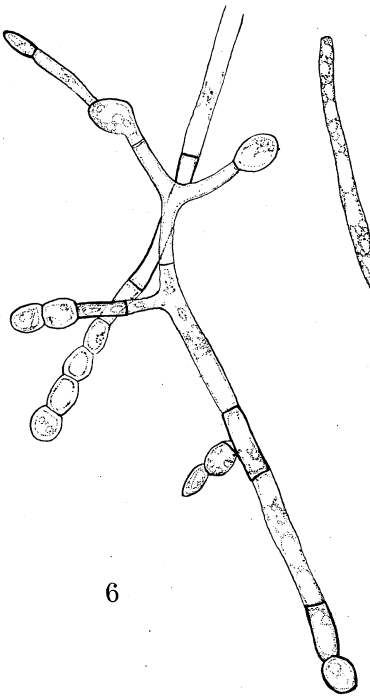

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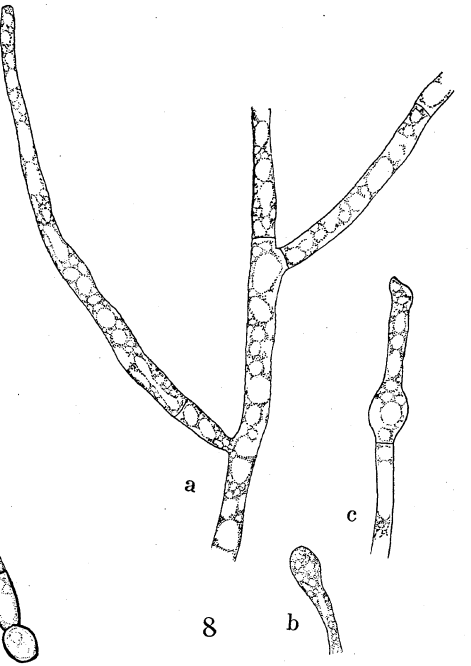

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THE WATER MITES OF THE JORDAN LAKE REGION

RUTH MARSHALL

Jordan Lake is in the extreme southwestern part of Adams County, Wisconsin, fifteen miles from Kilbourn and the Dells of Wisconsin River. It is one of a group of small lakes, ponds and pools, all situated within an area of some five square miles. This lake is about one mile long, irregular in shape, with a large extent of marshy and weedy border. A few rods away to the west lies Goose Pond, a very shallow spring-fed body, irregularly C-shaped, with a surface of about five acres; it is choked with water plants and teems with small animal forms. Haynes' Pond, a similar body of water, lies a short distance to the north of Jordan Lake and there are also three very small pools in the immediate neighborhood. About two miles north of this region lie three small lakes somewhat similar to Jordan Lake, Parker, Deep and Crooked, and beyond these is Goose Lake. At the village of Oxford, three miles north-east of Jordan Lake, is a pond which has been dammed. South-east of Jordan Lake are two other mill ponds near the village of Big Spring, while some three miles eastward from these, near the village of Briggsville, lies Lake Mason, the largest lake of the region. In all, these bodies of water afford a rich collecting ground for aquatic forms.

In the summer of 1927 the writer spent four months at Jordan Lake working on the hydracarina. Collections were made in all of these bodies of water, but especially in Goose Pond, which was visited once a week. The Birge cone net was used in securing material; it was cast from shore, or in a few cases, thrown from a boat or dragged through shallow water. In addition, a few clams from Jordan Lake were examined for parasitic mites.

Nearly fourteen hundred individuals were obtained in some forty collections from these waters, of which number about one thousand have been identified. It appears probable that this is a fair representation of the water mite fauna of the shallow waters of this biological area.

Nineteen genera with fifty-nine species and varieties were found, of which four of the latter are new, while several new records were established for the state. The "red mites" were present in large numbers; about two hundred individuals were found, the greater number of which belong to the common species *Hydryphantes tenuabilis.* A few specimens of Eylais were present, but only one species was identified with certainty *(E. desecta).* About one-third of all of the individuals were Pionas, most of which were assigned to eleven recognized species. The Limnesias comprised about one-fourth of all individuals and represented six species, the great majority being *L. fulgida wolcotti.* The Arrhenuri were abundant and very rich in species, eighteen being recognized, with a number of unidentified females.

Descriptions of the new species, notes on certain new records and a list of the species follow.

Hydrachna schneideri americana Mar.

Pl. 5, Fig. 8

Four individuals of this species were found in the two ponds at Big Spring. One of these proved to be a young male, the sex not previously described. The epimera are in form like those of the female; the fourth, which is somewhat angular, nearly encloses the genital area. The male genital plates in this variety are similar to those of the parent species, but are not so elongated.

Hydrachna rotunda nov. spec.

Pl. 5, Fig. 4, 5

The color is deep red. The body is rotund, 1.20 mm. long. The surface shows small papillae. The dorsal plates are represented by two very small somewhat crescent-shaped pieces just anterior to the center of the body, near which are two small muscle attachments. The fourth epimera are nearly rectangular except for the slim projecting inner lower corner of each. The male genital area is large, obovate, and is nearly enclosed by the last epimeral pair. The palpi are slim. The female is unknown.

One young male was found in Goose Pond. The species has

also been found in two other places in the state (Green Lake and a pool near Green Bay).

Hydrachna crenulata nov. spec.

Pl. 5, Fig. 6, 7

The color is deep red with indistinct deep blotches; the eyes are very dark red. The body is circular in outline, highly arched and has two slight projections between the eyes. It measures 1.92 mm. The surface shows faint papillae. Dorsal plates are not developed, but there is a small thickening near a large hair papilla some distance back of each eye. The epimera are heavy, with rounded corners, and the groups are close together. The male genital area is cordate in form, closely and almost entirely surrounded by the last epimeral pair.

The female is unknown. One male was found in a pool near Oxford.

Hydryphantes ruber (de Geer)

Pl. 6, Fig. 9, 10

One adult, found in one of the pools near Jordan Lake is referred to this common European species. The epimera and genital area agree closely with Piersig's figure in Zoologica (fig. 130, a). The dorsal plate, however, does not agree so well with this and other published descriptions, being relatively narrower with more conspicuous posterior prolongations. But, as the figures of various authors show some degree of variation, the present identification seems justifiable. Figures are submitted in confirmation of this opinion.

Hydryphantes multiporus nov. spec.

Pl. 5, Fig. 1–3

The color is bright orange red and the surface is finely papillose. The larger of two adults found measured 1.50 mm. The large dorsal shield has conspicuous posterior lateral prolongations and closely resembles that of *H. alienus* Lund., reported from Peru. The epimera have the usual form; the fourth show a considerable convexity where they approach the genital plates. The genital area is distinguished by the great

number of acetabula present on the plates; these are variable in number, even in the two plates of the same individual. There is an acetabulum on either side close to the genital slit and from fourteen to eighteen arranged around the outer margin of each of the plates. In the allied species there is likewise a large and variable number of acetabula, but the range is not so great. In the nymphs this variability is likewise shown: in the seven specimens found, while the left plate bore always five, the right one in two individuals bore an additional acetabulum (one very small), and two specimens, one a very young one, had but four on this side.

The legs are stout; the last one is about the length of the body. The first three pairs bear many stout bristles, especially on the distal ends of the segments. The second and third pairs have a few long coarse hairs on the fourth and fifth segments; the fourth legs have more and longer hairs. The palpi are stout.

The nine individuals described were found in Goose Pond and a nearby pool in June and mid-July.

Atractides jordanensis nov. spec.

Pl. 6, Fig. 12–14

The body is nearly circular in outline, compressed, the dorsal and ventral parts separated by a deep lateral furrow. The surface of the body and appendages is conspicuously papillose. The largest males measured 0.985 mm. The colors are conspicuous, red orange predominating; a reddish area borders the circumference while farther in are irregular blotches which may be brown or pink on a ground color of pale yellow. Younger individuals show a more variegated pattern and brighter colors. The eyes are red.

There is a large dorsal plate with four well defined smaller ones on its anterior border, the middle two smallest, nearly trapezoidal, the lateral ones elongate. In this respect the new species resembles *A. anomalus* Koch. The epimera are typical of the genus except that the united first pair are small and the anterior margins of both first and second do not project very far over the body margin. The genital plates of the male are typical, being nearly surrounded by the united third and fourth epimera. The capitulum is very small, the rostrum is little

developed. The palpi are small and stout; there are numerous bristles on the palpal segments, some of which are slightly feathered, while hair papillae are little developed. The legs are short, the fourth about the length of the body; there are many heavy bristles, with a few swimming hairs on the last three pairs.

Twenty five individualus, all males, were found in nine collections in debris from Goose Pond and in two collections from Jordan Lake. They were found in June, July and August; young individuals appeared in late August.

Piona conglobata (Koch)

Pl. 6, Fig. 11

Two collections from Oxford mill pond gave seven individuals (one male, five females, one nymph) of this cosmopolitan species, the first record to the author's knowledge for America. The specimens have been compared with material identified by Dr. Viets. The color was dull yellow with brown patches, a faint red showing in the center of the body. The scattered acetabula of the female genital area are variable in number and position.

Arrhenurus birgei Mar.

Pl. 6, Fig. 16, 17

The female of this common species has now been definitely identified. The body is ovate, 0.85 mm. long, the posterior end slightly projecting. The fourth epimeral plates are narrow on the inner borders. The wing-shaped genital areas project nearly straight out from the genital cleft.

List of the Species

1. Eylais desecta Koen.
2. Hydrachna schneideri americana Mar.
3. Hydrachna rotunda nov. spec.
4. Hydrachna crenulata nov. spec.
5. Hydryphantes tenuabilis Mar.
6. Hydryphantes ruber (Geer)
7. Hydryphantes multiporus nov. spec.
8. Diplodontus despiciens (Müll.)
9. Lebertia quinquemaculosa Mar.
10. Lebertia porosa Thor
11. Oxus connatus Mar.
12. Frontipoda americana Mar.
13. Atractides jordanensis nov. spec.
14. Limnesia fulgida wolcotti Piers.
15. Limnesia undulata (Müll.)
16. Limnesia maculata americana Piers.
17. Limnesia columbica Mar.
18. Limnesia paucispina Wol.
19. Limnesia cornuta Wol.
20. Megapus parviscutus (Mar.)
21. Unionicola crassipes (Müll.)
22. Unionicola aculeata sayi Piers.
23. Neumania semicircularis Mar.
24. Neumania punctata Mar.
25. Neumania extendens Mar.
26. Koenikea concava Wol.
27. Forelia ovalis Mar.
28. Piona rotunda (Kram.)
29. Piona reighardi (Wol.)
30. Piona inconstans (Wol.)
31. Piona setiger (Wol.)
32. Piona media (Wol.)
33. Piona conglobata (Koch)
34. Piona pugilis (Wol.)
35. Piona crassa (Wol.)
36. Piona debilis (Wol.)
37. Piona turgida (Wol.)
38. Piona constricta (Wol.)
39. Hydrochoreutes ungulatus (Koch)
40. Mideopsis orbicularis (Müll.)
41. Albia caerulea Mar.
42. Arrhenurus rotundus Mar.
43. Arrhenurus crenellatus Mar.
44. Arrhenurus scutulatus Mar.
45. Arrhenurus infundibularis Mar.
46. Arrhenurus birgei Mar.
47. Arrhenurus manubriator Mar.
48. Arrhenurus parallelatus Mar.
49. Arrhenurus marshallae Piers.
50. Arrhenurus megalurus Mar.
51. Arrhenurus pseudocylindratus Piers.
52. Arrhenurus apetiolatus Piers.
53. Arrhenurus magnicaudatus Mar.
54. Arrhenurus superior Mar.
55. Arrhenurus americanus Mar.
56. Arrhenurus reflexus Mar.
57. Arrhenurus pollictus Mar.
58. Arrhenurus falcicornis Mar.
59. Arrhenurus laticornis Mar.

Rockford College,
January 10, 1930.

Explanation of Plates

Plate 5

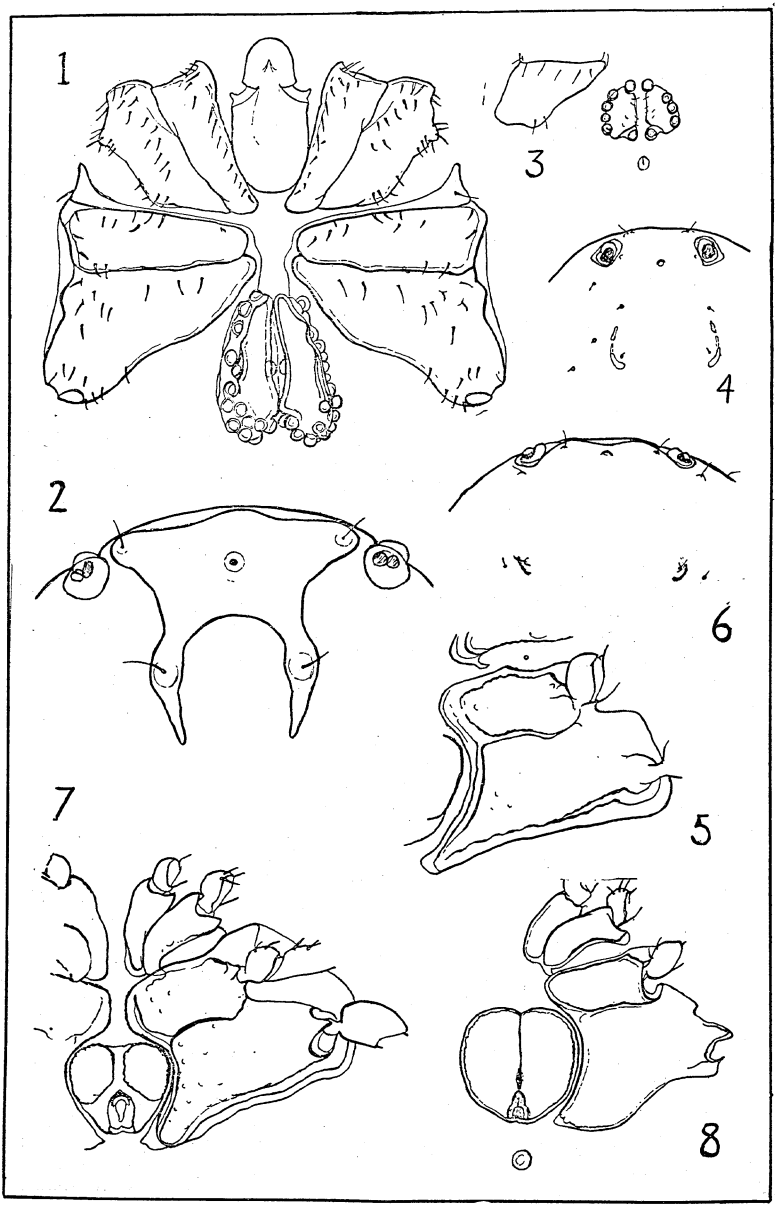
Fig. 1. Hydryphantes multiporus, ventral plates.
Fig. 2. Hydryphantes multiporus, dorsal plate.
Fig. 3. Hydryphantes multiporus, genital area of nymph.
Fig. 4. Hydrachna rotunda, anterior dorsal region.
Fig. 5. Hydrachna rotunda, third and fourth epimera, left side, male.

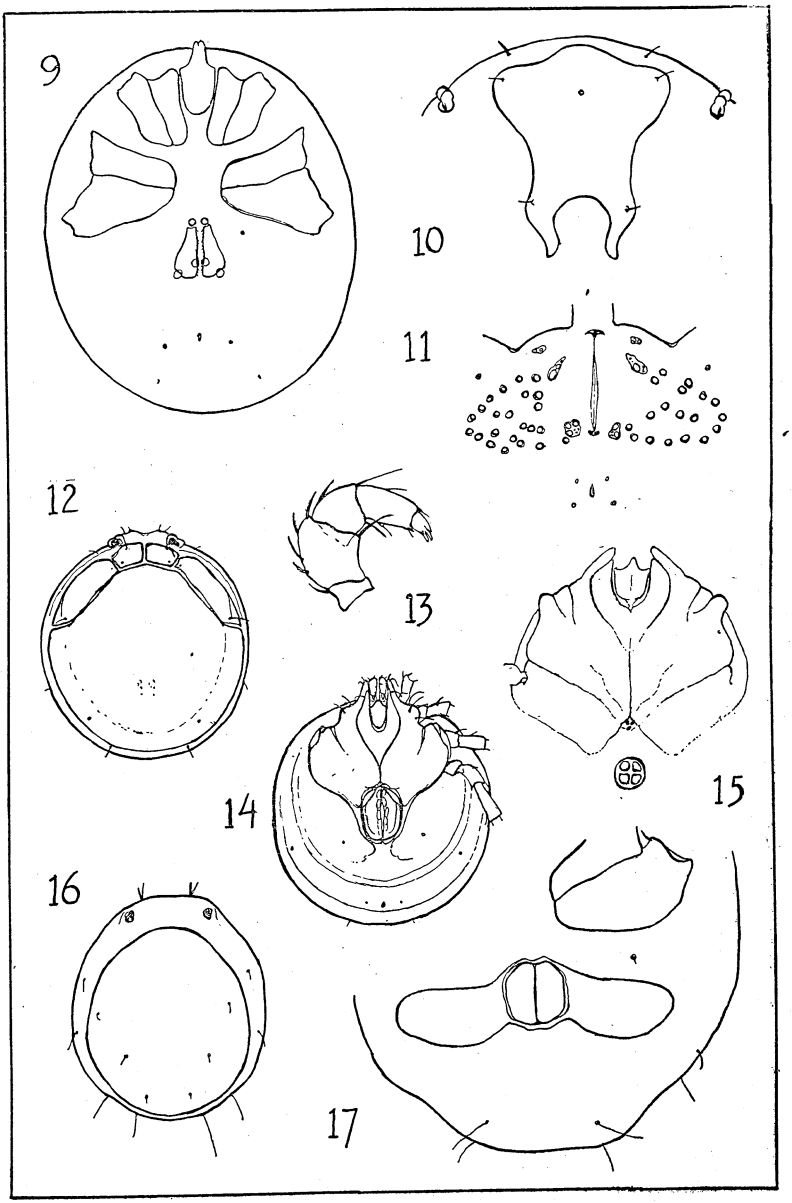
FIG. 6. Hydrachna crenulata, anterior dorsal region.
FIG. 7. Hydrachna crenulata, ventral plates.
FIG. 8. Hydrachna schneideri americana, male genital area and left epimera.

PLATE 6

FIG. 9. Hydryphantes ruber, ventral surface.
FIG. 10. Hydryphantes ruber, dorsal plate.
FIG. 11. Piona conglobata, genital area of female.
FIG. 12. Atractides jordanensis, dorsal surface.
FIG. 13. Atractides jordanensis, right palpus.
FIG. 14. Atractides jordanensis, ventral surface of male.
FIG. 15. Lebertia quinquemaculosa, ventral plates of nymph.
FIG. 16. Arrhenurus birgei, dorsal surface of female.
FIG. 17. Arrhenurus birgei, genital area of female.

TRANS. WIS. ACAD., VOL. 25 PLATE 5

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THE HYPODERMAL GLANDS OF THE BLACK SCALE, SAISSETIA OLEAE (BERNARD)

II. The Ventral Glands

Wm. S. Marshall
University of Wisconsin

When the study of the hypodermal glands of the black scale (Saissetia oleae) was started and a number of sections of insects of different ages had been examined, it became evident that the work would be a fairly long one and therefore, as the position of the glands upon the body made it easily possible, the work has been divided into two parts. The first section treating of the glands found upon the dorsal surface of the body was published in the last volume of these transactions, the second and last portion, the ventral glands, is contained in this paper. Nothing has been done to prove the function of the different types of hypodermal glands possessed by these scale insects, but two questions at once arise; are they all glandular in function and, if so, what in the life of these sedentary insects would necessitate the possession of so many glands opening to the outer surface of the body.

The slides used for this study were, in great part, the same from which the work on the dorsal glands was made, consequently the methods of preservation and staining of the scale insects will not be repeated; they can be seen by consulting the previous paper (6). One change, however, was this: wishing to examine only the ventral glands a number of mature insects were sectioned after the thick dorsal cuticula had been removed; this was easily done by cutting out the body of the scale insect after it had been preserved. The insects were placed in a watch glass of alcohol under a binocular and then, with a fine dissecting knife, nearly the entire body could be removed; it was thus very much easier to section the insect than when the dorsal wall was intact.

After studying the glands upon the ventral surface of the body it was found possible to place them in three groups or

types. The first of these was very distinctive and entirely different, principally in the possession of its long duct, from any of the others; the glands of the second type were easily distinguished by their size and shape and the restriction in their location. The glands of the third type were widely distributed over the ventral surface of the insect; they were not so characteristic as the other two types. This last group of glands did not show the similarity in structure of the other types; they can, however, all be placed together and will be so treated in the present paper.

First type, the stalked glands. The first noticeable appearance of these glands was in early second instar larvae, no trace could be found in those of the first instar; all that could be seen in any of the youngest glands was a small irregular mass of protoplasm containing one or two nuclei and in the center, a little nearer that surface of the young gland facing the cuticular layer of the body, was a clear rectangular space, the beginning of the future duct (fig. 1). Due, as one viewed the section, to the smaller amount of protoplasm above and below the duct than at either side this central part appeared lighter than the rest of the gland. In nearly all specimens a nucleus could be seen at either side of the duct; there might have been more than two of these in each gland as all specimens studied were in sections and other nuclei, if present, might have been removed or hidden from view. An opening through the adjacent cuticular layer of the body was not observed in any of the youngest glands although such must always be present as each gland undoubtedly develops as an invagination of the body wall. Glands similar to these of the black scale have been described in other coccids (9, 16, 17), but no attempt has heretofore been made to trace their development.

The duct lengthens and pushes the gland a little further into the interior of the body; other than this no difference is seen between a slightly older stage (fig. 2) and the one shown in the first figure. Due to a slight increase in the size of the gland, more nuclei can now be seen and the opening of the duct to the outside is discernible. This duct is very small so that most sections do not show it; to be visible the gland must be cut directly through its center and at the proper angle; this accounts for the outlet of the gland not showing in most of the young specimens figured.

The gland begins to lengthen and its duct, running longitudinally through about two-thirds of its central part, grows longer (fig. 3); it has, of course, increased in size and contains more nuclei which are now arranged around the duct to form, as in the regular hypodermis of which it is an invagination, a single layer of cells. In this specimen and a somewhat later one (fig. 4) the gland is nearly straight and more or less at right angles to the cuticula; its apical portion is often slightly bent and this is shown by a darker terminal portion due to the end, in many specimens, turning away from or towards the observer.

The duct present in the youngest glands is a straight tube which, when the gland lengthens, passes longitudinally through the proximal two-thirds or three-quarters of its length to open through the cuticular layer. Very early in development there appears, from its distal end, a second tube, a continuation of the first one; this second one is smaller in diameter than the original tube and is slightly curved. It arises at the margin of the free, distal end of the original duct and grows out into the terminal portion of the gland (figs. 4 and 5) which it follows in its growth and is, as is also the original duct, surrounded by a single layer of cells, the developing gland. Coincident with the development of this smaller tube one or two of the nuclei of the gland become larger than the others (figs. 5, 6 and 7).

After the formation of the smaller part of the duct the next most noticeable change is the development at its apical end of a bladder which first appears as a small, clear, space, a continuation and enlargement of the duct into which it opens. The bladder is surrounded by protoplasm; at first no nucleus is seen adjacent to it (figs. 6 and 7), but later one or two, the largest in the gland, come to lie close to its margin (figs. 9 and 10). There is some doubt about there being two of these large nuclei, although sections can be found in which this number is present; sections only were studied and in these two parts of a single large nucleus might be mistaken for separate ones. When one examines the older glands it is evident that there is a single, very large, terminal nucleus which occupies, relative to the other parts, about the same position in all the glands. With the growth of the bladder this large nucleus assumes a more terminal position in the gland and the thin layer of protoplasm

which at first surrounds it increases in amount to become one of the main portions of the gland.

The bladder is at first clear and transparent (fig. 8), but in many specimens it soon shows a reticular structure due to the first appearance of the thickenings of its wall (figs. 6 and 7); these are very noticeable in all the older stages. The bladder, as well as its duct, has a cuticular lining and any irregular thickenings of its wall will account for the markings which in its development soon become apparent. Most of these thickened parts appear as strands over the surface of the bladder, some are branched and in other ways they are more irregular than shown in figures 11 and 12. The use of these cuticular thickenings is, no doubt, to strengthen the bladder; this might be necessary when some other part of the body presses against the gland. Many of the glands extend free into the body cavity, such have a regular shape (fig. 15); others in their growth press against some other tissue of the body and this may cause them to assume irregular forms. A few of the glands which lie far out near the margin of the insect's body may, in their growth, come against the dorsal body wall and would then necessarily become bent. A normal gland (fig. 15), pyriform in shape, extends into the body cavity more or less at right angles to the surface of the insect's body; many more are bent although in these the larger proximal part of the duct is nearly always straight, but often at an angle to the cuticular layer.

In most of the glands figured showing the position of the smaller duct as it emerges from the larger one, it appears to arise at some position at the distal end of the latter. In very many of the specimens it is seen to come off from the central part of the end of the larger duct; in others at one side and again from any position between the center and the margin. In some sections one gets the continuation of the ducts in such a position that the real origin of the smaller from the larger one can be correctly seen and their relation to each other determined. Such a view (figs. 11 and 15) shows that at one side of the distal end of the larger duct there is a slight outpushing of the rim; this extends but a short distance and ends blindly, opposite this there is another outfolding which does not end blindly but becomes the smaller duct to terminate in the bladder, its inflated end.

All parts of the gland, its bladder and duct, are now formed

and the only change to hereafter take place is one of growth, the enlargement of the gland and its bladder. In the wall of the bladder the irregular markings soon become noticeable as a number of rib-like thickenings which in most of the sections, where a part only of the bladder can be seen, appear to pass along the periphery to its outlet at the opening into the smaller part of the duct (fig. 12). In some mature insects the strands are much more noticeable than in others; this may be due to a real difference in the thickness of the bladder's wall or to the different methods of preservation and of staining. In sections of the bladder the markings appear as alternate thinner and thicker portions of the wall, somewhat like the taenidium in a longitudinal section of a large trachea, only without such regularity (fig. 15).

In each instance the gland, the bladder and the large terminal nucleus increase in size; the length of the duct varies and this depends upon the location of the gland and its chance of being retarded in its growth and of not reaching its maximum length. Near the margin of the insect's body this may be influenced by the proximity of the dorsal wall, in other situations by the presence of other organs; these same things make the difference between a straight and a bent gland and the majority belong to the latter category. Figure 15 is an example of a gland growing free in the body cavity; from this specimen one can get a good idea of the relative size of the different parts of the gland as found in mature insects. The term mature insect has been given to those specimens of the black scale within whose body embryos are present.

That these stalked glands are actively secretory is shown not only from their structure but from the fact that in several sections the secretion is visible which has been poured out from the duct. This secretion is not often seen within the bladder, but in some sections it can be observed as an accumulation on the ventral surface of the scale insect and near the opening of the duct. The slides used were all cleared with xylol in which the preparations were placed twice, once when the entire insect was being transferred into paraffine and again, after staining, when the sections were cleared; the presence of the secretion in some of the sections shows that it was not entirely, if at all, dissolved by the clearing agent. The secretion formed by the glands and seen in the slides was clear; it contained a number

of small vacuoles which were scattered irregularly throughout its mass (fig. 14). One specimen showed the presence of some secretion entirely filling the duct and protruding from its opening; it was black, but whether its dark color was due to some abnormality could not be determined. In this same gland the contents of the duct could easily be followed from one end to the other and, while no mass of secretion was seen along the surface of the insect where the duct opened, one could easily determine that something had been flowing from the duct by a slight protrusion from its opening (fig. 15).

If a black scale be examined while still in its more flattened condition, it will be seen that there is a marginal area which is rather flat; here the dorso-ventral diameter is quite short as compared with the median one. From this marginal area on the ventral surface a thin, colorless, waxy layer can be scraped away. After the insect becomes adult and its body form changes to become somewhat hemispherical in shape, the flat marginal area is lost and there is formed a fleshy lip-like flap which runs entirely around the body near its margin; an unsuccessful effort was made to find this marginal secretion in old insects. These stalked glands are of course ventral; they are confined in great part to the marginal region of the body and are especially abundant near its anterior end. They may be entirely separated from each other or crowded together in groups (fig. 16). This marginal location corresponds to the layer of wax which we have just mentioned.

Gland number two. The ventral gland, which is here designated as number two, has already, at least others of a very similar structure, been described in several coccids; in the descriptions of these glands they are given as situated around the genital opening, in the vagina or scattered over different parts of the body. This type of gland in the black scale would not be given here were it not that they are found, sparsely it must be admitted, on the ventral surface of the body; a similar but larger gland, the spinneret, is also found in groups in the terminal portion of the vagina. Childs (2) has described a group of glands in *Epidiaspis piricola* which he calls the circumgenital glands or spinnerets. The elongated cells, seven cells in each unit, of these glands are held together by smaller supporting cells and a duct leads from each gland—opening to the outside through a circular pore. These spinnerets were not found

in the larval stages of the insect, but develop later and function when the scale insect becomes mature. Berlese (1) figures, from *Guerinococcus serratulae,* a gland which is similar to our number two; the cells of these he describes as much shorter than those found in the regular spinnerets. Kitao (5) describes somewhat similar glands which he says are scattered among the spines; he also mentions the spinnerets. Oguma (11) mentions two kinds of wax glands; one, similar to the spinnerets, has a cuticular pore with a sieve-like opening not situated at the surface, but a short distance below it; these glands he locates in the perianal region of the larvae and of the female imagos. The second gland he describes is very similar to our number two; this is present "nearly everywhere underneath the chitinous integument of the larvae, but also in adults". Matheson (8) writes of a gland which is particularly abundant about the genital opening, but is also scattered over the ventral surface on the lateral margins of the body of the insect. This gland consists of from seven to eleven cells plus a terminal one which forms a kind of stopper. The pore is a circular opening, chitinous ring, in which there are usually ten small holes. Matheson's third type of gland is much like the number two we describe, but is smaller than ours and has a different pore. Teodoro (17) describes glands similar in structure and in pore opening to the spinnerets. The spinnerets that have been described by these workers in the different coccids were all quite similar in structure and closely resemble the corresponding glands in the black scale.

There are, opening into the last part of the female reproductive organs of the black scale, a number of long, narrow glands; these are grouped very close together and a few are also found on the body surface very close to the genital orifice. In this insect their function as spinnerets is very doubtful; the black scale is an egg-laying insect, but does not show the white cottony mass which is often seen underneath many other coccids. If a mature black scale is removed from a plant upon which it is feeding and its ventral surface examined under a binocular, one will easily see what at first appears to be a white fluffy mass that could readily be mistaken for waxy filaments; a close examination shows that this is nothing but a group of empty egg shells which, after the emergence of the larvae, have collected under the scale.

The spinnerets in the black scale are close to each other, packed together, as it were, around this proximal portion of the female reproductive organs and whatever liquid they secrete could easily reach the under surface of the body or mix with the eggs just as they were leaving the mother. Seen in surface view the openings of these glands appear as circular, glistening, cuticular plates not touching each other but close together so that one can see eight or ten of them in one section. The use of the secretion from the glands might be to fasten the eggs to each other as they are deposited under the scale; as already mentioned no waxy filaments were seen on the under surface of the insect's body.

The spinneret of the black scale (fig. 17) consists of a number of long narrow cells each widest at its basal end where its nucleus is situated; the entire gland is also widest at this end, decreasing in diameter as it passes towards the surface of the body to finally become narrower than the width of the circular pore-plate through which it opens to the outside. In a few of the specimens one could see a duct which extended for a short distance from the cuticular plate down into the gland. The plate through which the duct opens is similar to those of the smaller glands found externally on the ventral surface and will be described with them.

On different parts of the ventral surface, but not nearly as abundant as the other glands (spinnerets excepted and they are restricted to one locality) are a number of small, gland-like structures which are differentiated from the other glands and easily separated from all but the spinnerets by the form of their cuticular pore-plate. These glands, not abundant, were found only on the posterior part of the abdomen near the median axis of the body; they are also present near the genital orifice. Of the function of these glands nothing is known; they appear as if they were spinnerets which had wandered out on the ventral surface but failed to reach their full growth.

The smallest of these glands was found in a fairly old second instar larva (fig. 18); there was a slight invagination of the hypodermis and in this part its cells were a little deeper and the nuclei slightly larger and darker staining than the neighboring normal cells. The changes noticed at this region in the hypodermis are hardly definite enough to satisfy one that this is the beginning of the development of any gland, but the over-

lying cuticular plate makes identification positive; this plate is hard to figure in section but enough of its structure can be seen to satisfy one as to its identity. A number of these young glands, similar to the drawing, were found, all present on the abdomen.

After this type of gland has reached its full development (fig. 19) the individual cells composing it are long and narrow and each has a nucleus near its base; the central are longer than the peripherial cells. Nothing resembling a duct was observed but each cell of the gland narrows to a neck and ends against the inner surface of the cuticular sieve-pore. The number of the cells in the gland might correspond to the pores in the cuticular plate thus giving each cell its own opening to the outside; they could also join, as seems probable from an examination of those observed, and the secretion would then be filtered as a mass through the exit pores and leave the gland as a number of separate filaments corresponding to the number of pores in the pore-plate.

The openings of these glands are similar to those of the spinnerets and one description will suffice for both. In section a saucer-like depression is seen in the cuticular layer and from the bottom of this four, this is the most constant number, teeth protrude towards the opening (figs. 18 and 19). The two central teeth undoubtedly show the limits of the central circular part seen in surface view (fig. 20). Between these two innermost teeth and the next outer two, lie the pores. A glance at the surface view will show a central circular piece; this might be an opening, but I am inclined to think that it is part of the cuticular layer having a different appearance than the rest of the disk. About eleven oviform pores are arranged in a circle, symmetrically, around this central disk and these form the openings through which the secretion passes to the surface. An outer cuticular ring forms the boundary of the plate. Murdock (10) describes in *Icerya purchasi* a compound pore similar to what is found in the black scale; he shows a central pore of two openings and this is surrounded by a circle of from eight to twelve small pores. If the central circular part of the plate in the black scale consisted of two openings the similarity of the pores in these two scale insects would be very pronounced.

One specimen of this type of gland found in a mature scale

insect showed some modifications from that just described. The larger, basal, part of the gland was just as described, but each cell as it approaches the sieve-pore separates from the others and a narrow space is thus formed between the different cells. One might assume from this that the cells of the gland were equal in number to the pores and that each one had its own exit-pore through which the secretion reached the surface.

Third type gland. These glands appear very early in larvae of the first instar and were noticed in some but a few hours old; they are found scattered over the ventral surface of the insect's body, more numerous near its margin than the median part. None of the early developmental stages of these glands were found; in the young larvae in which they were first observed they were already well formed and it became a matter of tracing their growth and any changes which took place in the relative increase in the size of their different parts. The first study of these glands led one to believe that there were two kinds: the one smaller both in actual size and as compared to the insect's body, the other was much larger both proportionally to the other gland and also as compared to the actual size of the insect; the bladder in this larger gland was very conspicuous and in many larvae it was filled with a substance, generally taking the form of strands, which often stained with haematoxylin. These two apparently different types of glands could be found in the same young larvae and one section was seen containing both kinds, one on either side of the insect's body. As larvae of different ages were examined it was evident that the glands all belonged to one type, but might show different stages of their growth in the same larva; both were found very early in the life of the insect and were also present in older larvae. In the mature insect all of these glands appeared to disintegrate, becoming irregular in shape and content.

The youngest of these third type glands was found in a larva which had emerged but a few hours before it was preserved. This gland (fig. 21) shows that all its parts are developed; it is more regular in outline, but its bladder and duct are similar in general structure to what is found in the older larvae. The duct leads through the cuticular layer of the body to end in the bladder. The gland consists of a single layer of nucleated cells, at least it has that appearance although no cell boundaries could be seen, and, at this early stage, the nuclei of these cells

show considerable differences in size. Each of these glands most probably originates as an invagination of the body wall and retains its connection with the outer surface by its duct. The normal hypodermal cells of the body wall surrounding the gland's duct are flattened but often fail to show any direct connection with the cells of the gland.

In specimens of the black scale which are undoubtedly young second instar larvae, or older, glands can be found which are as small as that just figured from a young first instar larva. In such a gland (fig. 22) a number of small nuclei are present, but no real difference is noticed in the general structure of these two glands. This would show that these glands did not all first appear in very young larvae, but that for a certain time during the life of the insect they increase in number with its age and, as one would expect, more of them are present in larger than in smaller larvae.

Other than the increase of the gland in size, the most noticeable feature during its growth is the appearance in the bladder, which increases in size with the gland, of the secretion which, in many specimens, takes the form of strands; many of these end at that part of the bladder where it opens into the duct (fig. 28). Somewhat similar strands have already been noticed in the bladder of the stalked glands, but in these they were always of a yellow color and undoubtedly thickenings of the cuticular lining of the bladder. We find that in the third type glands these strands are not like this but that, after reaching a very pronounced size, they take the color from the haematoxylin stain and have the appearance of irregular strands within the bladder, not thickenings of its wall.

Just what the sequence of this secretion formation is and how it takes place, if always in the same way, is uncertain as the short description here given has been taken from larvae the comparative ages of which, except in a general way, were unknown. The black scale in its development passes through instars in each of which great changes take place both in the size of the larvae and the growth and development of their organs; it is therefore difficult to distinguish the younger from the older larvae when they are of nearly equal size. The first instar can be differentiated from the second both when viewed externally and in sections but, from a study of the latter, it is difficult to tell comparative ages. If this type of ventral gland

has as its function the secretion of the exuvial fluid, they should tend to be most active and their contents greatest before ecdysis. If this is their only use, why are so many present? It has already been shown that some of these glands are found to be just starting their growth during the second instar; if they are exuvial glands the larger larvae would, for their ecdysis, require more exuvial fluid than those of smaller size and one might expect to find more of them on the larger larvae; this is so.

There is no definite size of the gland at which the secretion first appears; in the growth of the gland it and its bladder become enlarged and the latter may be clear in large glands or, in much smaller ones, show signs of the secretion content. In some second instar larvae, the glands are not nearly so large, both in actual size and relatively to the insect's body, as many found during the first instar. There are other glands which are in part or entirely filled with a granular content instead of the more frequent strands. A number of small first instar larvae show few extremely large glands which occupy a relatively large space in the body cavity of the insect. In the larvae, until they are very large, the size of the gland may have nothing to do with the comparative size of the body; this also is true of the size of the bladder in proportion to that of the gland; in some larvae it fills most of the gland, in others it is comparatively small. When the secretory strands first appear (fig. 24) they are found in glands of various sizes; in the small ones they are noticed as rather delicate threads passing across the bladder or partially around its circumference and in this early stage they were faint in outline and did not take the color of the staining fluid. With the increase in size of the bladder the strands, if present, generally enlarge and run more together; they thus lose, in part, their strand-like appearance (fig. 26) until they finally form masses of secretion connected by strands passing from one to the other (fig. 27).

When one studies these glands in the mature insect, they show a similarity which is quite evident; at first many differences are observed in size and appearance, but a close examination shows that they have a certain resemblance to each other which would place them all in the same type of gland. In these third type glands of the adults, the external form is often in a collapsed condition with irregularities in outline;

changes which have taken place in the content or structure of the gland are also most noticeable. The bladder is generally empty, but in some specimens its basal part is filled with what may be a secretion; in some specimens this shows as an irregular granular mass, in others it takes a light blue color which hides the structure of its contents. The wall of the bladder is very distinct, becoming thicker near the outlet of the duct and forming there a circular plate which extends part way down the bladder. The content of the gland proper has become very irregular, appearing as a mass of vacuoles and of glistening yolk or oil bodies; these are more crowded together and some are larger than is shown in the drawing (fig. 29). The outline of the large nucleus at the basal part of the gland is very irregular and its contents, although taking a blue color from the stain, shows no regularity of structure.

These third type glands were very numerous on the ventral surface, but we failed to find them in any definite arrangement in the body; they were present on the head, thorax and abdomen but much more numerous on the last region of the body. There appears to be no other use for the secretion of these glands than that of aiding in ecdysis; in the mature insects their appearance tends to show that their function has ended. The exuvial glands have been described from a number of insects and one can form conclusions by comparing these glands in the black scale with the exuvial glands of other insects.

In one specimen of a mature black scale, another kind of ventral gland was found (fig. 31); this might be taken as a modification of the second type were it not that the outlet of three or four of them was seen and each of these had an entirely different appearance (fig. 32) from any of the previously described glands. In the description of the second type of gland, mention was made of a few which showed a tendency to have their cells separated from each other before they reached the pore. This gland showed the same thing, but it was much more evident and there were alternate darker and lighter layers in the gland just before it reached the cuticular layer, making this separation of the cells very marked. In the main body of the gland, the nuclei were very plainly seen, but there was no appearance of a division into cells.

The opening of this gland, when seen in surface view, looked as if there were nine cuticular teeth surrounding a central pore

(fig. 34). These might correspond to the alternate dark and light parts in the gland, but of this we could not be sure.

SUMMARY

The glands on the ventral surface of the black scale, Saissetia oleae, can be grouped into three types. The first of these, the stalked glands, appear in early second instar larvae; at first small and nearly spherical they contain a very few nuclei and traces of a duct. They elongate and from the apical end of the duct develops a smaller one; this is slightly bent whereas the larger original duct is generally straight. At the terminal end of the smaller duct a bladder develops and upon its wall, as it increases in size, appear cuticular thickenings in the form of strands. A secretion can be found on the ventral surface of the insect near the outlet of the glands and a few specimens were observed in which a secretion filled the duct. These glands are present on the three body regions of the scale insect.

Glands of the second type, consisting of long narrow cells, are found, as spinnerets, inside the genital orifice. Similar glands, but much shorter, are present in small numbers on the ventral surface; they and the spinnerets open to the surface of the body through a cuticular sieve-plate in which are several small pores arranged in a circle. These glands are similar to the spinnerets, but their cells are shorter.

The third type of glands, probably all exuvial, are very abundant and are found on all parts of the ventral surface of the insect's body. The youngest seen, on very early first instar larvae, are small, round glands with a narrow straight duct leading to the outside. The duct comes from a bladder which in many specimens is very large relative to the size of the gland. Many glands show a secretory mass within the bladder. In the preserved specimens this secretion is in the form of strands. In the mature insect the glands are larger, but at this age of the insect they disintegrate.

Another kind of gland was found but only in two specimens and but very few of the glands on either of these insects.

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EXPLANATION OF PLATES

Cu., cuticula.
Duct', smaller duct.
Duct, larger duct.
Hyp., hypodermis.
Od., entrance of duct into bladder.
Scr., secretion.

Figure 16 has been multiplied 105, all the other figures 1400 diameters.

Glands of the first type are represented in all of the figures in Plate I and figure 16 of Plate II.

The second type of gland is shown in figures 17–20 of Plate II.

Glands of the third type are shown in Plate II, figures 21–25 and Plate III, figures 26–30.

PLATE 7

FIG. 1. Young stalked gland from the head region of a first instar larva. The duct can be seen as a clear, rectangular space between the two nuclei; the part passing through the cuticula, Cu., to the outside was not present in this section.

FIG. 2. Gland situated on the posterior part of the abdomen of a very early second instar larva. Hyp., hypodermis, Cu., cuticula.

FIG. 3. A little older gland at the beginning of its elongation. Its end is turned towards or away from the observer, hence the darker terminal region. From the same larva as figure one.

FIG. 4. Gland from the abdomen of a larger larva than any of the preceding figures. The small secondary duct, Duct', appears at the end of the larger one, Duct, but it is doubtful if this will show in the figure after it is reduced in reproduction.

FIG. 5. Gland from near the posterior part of the abdomen of a larva about the same size as the last. The two ducts, the smaller one Duct', not

yet entirely developed, have been drawn slightly wider than they should be in order that they might show in the figure after it has been reduced in reproduction. Nu., large terminal nucleus, Duct, larger duct.

FIG. 6. Terminal end of a small duct showing the beginning of the formation of the bladder. The markings on the bladder are the first signs of the thickenings of its wall. From a fairly old second instar larva.

FIG. 7. Another figure of the smaller duct and terminal bladder. From same larva as figure six.

FIG. 8. A young stalked gland showing its parts already formed but not of full size.

FIG. 9. The terminal bladder at the end of the small duct, adjacent to the bladder is the large nucleus.

FIG. 10. View of another bladder showing what are apparently two large nuclei.

FIG. 11. From an older gland having a single large nucleus near the bladder. The correct position of the origin of the smaller from the large duct is here shown as well as the small blind protrusion opposite it on the rim of the larger duct. Taken from a larva older than any of the preceding.

FIG. 12. An older gland showing a group of nuclei around the smaller duct. These are the nuclei of the row of cells surrounding this part of the gland and which can be seen, often imperfectly in sections, in these glands of the mature insects. In these last two figures the markings on the wall of the bladder are more regular than they appear in the specimens.

FIG. 13. The bladder of a still older gland. Part is shown cut away and below this opening is the small outlet of the duct, Od., towards which many of the thickenings on the bladder's wall are directed. From a nearly mature insect.

FIG. 14. Showing the duct, Duct, of a stalked gland passing through the cuticula, Cu., of the body wall on the outer surface of which is a mass of secretion, Scr., exuded by the gland. From a mature insect.

FIG. 15. The stalked gland of a mature insect. The large terminal nucleus is shown, also the few others around the smaller duct where in these fully developed glands there is a layer of large cells. The bladder is shown in section with the thickenings at its edge, each a section of a strand, formed by the cuticular lining of the bladder. The correct origin of the small duct from the rim of the larger one is shown as well as a secretion which fills the entire duct and protrudes from its opening to the outside.

PLATE 8

FIG. 16. Section showing a small portion of the lateral margin of the body of a black scale. The dorsal wall above shows some of the glands described in the first part of this paper. In the body cavity are seen a number of the stalked glands only one of which shows its opening to the outside.

FIG. 17. Spinneret from a mature black scale.

FIG. 18. Young gland of the second type. The enlarging hypodermal cells are shown, also the peculiar outlet or pore which is characteristic of this type of gland. From an old second instar larva, near posterior end of abdomen.

FIG. 19. A probable fully developed gland of this type. From near the genital orifice of a mature insect.

FIG. 20. Surface view of the sieve-pore of one of these glands, also of the spinneret. Within the genital orifice of a mature insect.

FIG. 21. Very small and young gland of the third type from what is probably a young second instar larva.

FIG. 22. Another very small gland from a young larva preserved a few hours after it has emerged from the egg.

FIG. 23. Gland from an old second instar larva. This shows the large nucleus, which with a number of smaller ones, can be found in all specimens. Very faint traces of strands within the bladder were present but these have not been drawn.

FIG. 24. Gland from a first instar larva. The secretion is shown in the faint, irregular strands within the bladder.

FIG. 25. Gland from a second instar larva. The bladder is proportionally very large to the size of the gland, in this specimen it is empty.

PLATE 9

FIG. 26. Gland from a first instar larva. This gland is also very large in proportion to the size of the insect, it is near but not at the lateral margin and its diameter is almost one-half that of the dorso-ventral diameter of the insect at this place.

FIG. 27. Bladder of a gland taken from an old first or young second instar larva. This shows the arrangement of the secretion somewhat similar to preceding specimen.

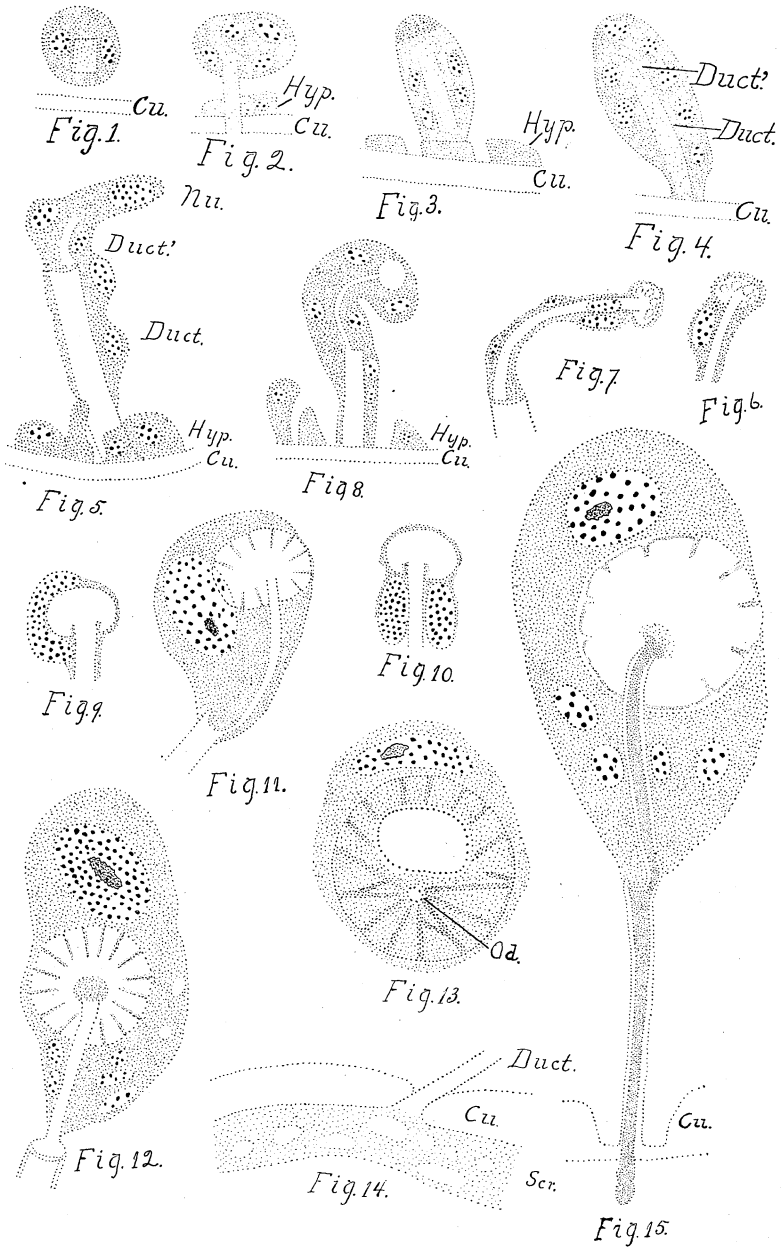
FIG. 28. Gland from an old second instar larva showing the tendency of the strands of secretion to end at the outlet of the duct.

FIG. 29. Gland from a mature insect. The irregularity of the bladder, the vacuoles in the protoplasm and the disintegration of the nucleus are at once noticed.

FIG. 30. Diagram showing the thickening of the wall of the bladder around the pore.

FIG. 31. An odd gland not fitting in with any of the other types. The gland itself is similar to those of type but has a different opening to the outside.

FIG. 32. Surface view of the opening of a gland similar to that shown in preceding figure.


Cu.
Fig. 1.
Hyp.
Cu.
Fig. 2.
Hyp.
Cu.
Fig. 3.
Duct'
Duct.
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Nu.
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Fig. 5.
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Fig 8.
Fig. 7
Fig. 6.
Fig. 9.
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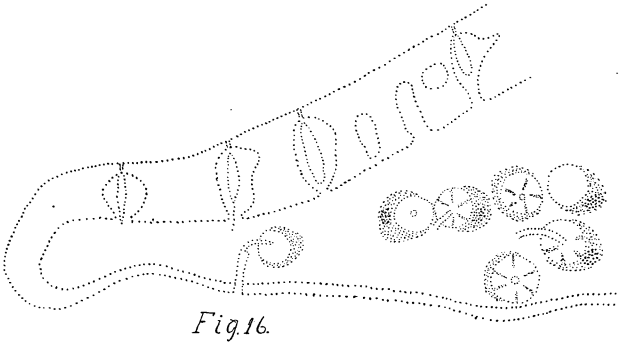

Fig. 16.

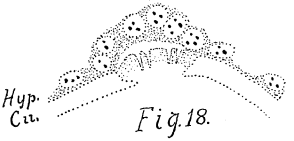

Fig. 18.

Fig. 20.

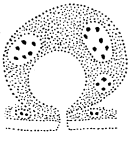

Fig. 21.

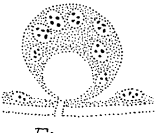

Fig. 22.

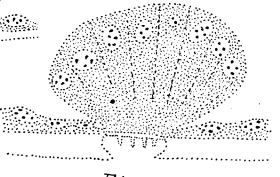

Fig. 19.

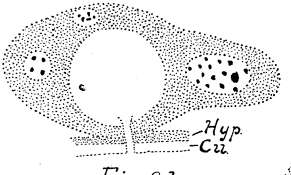

Fig. 23.

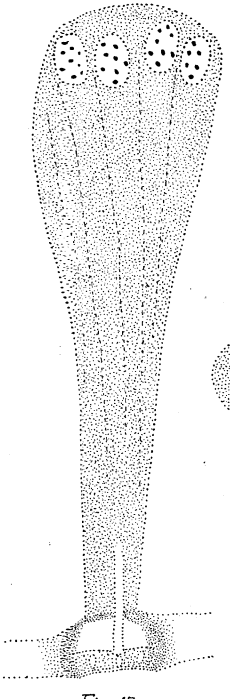

Fig. 17.

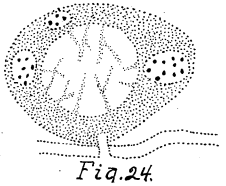

Fig. 24.

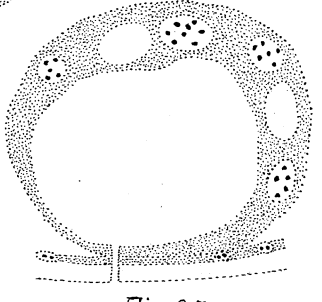

Fig. 25.

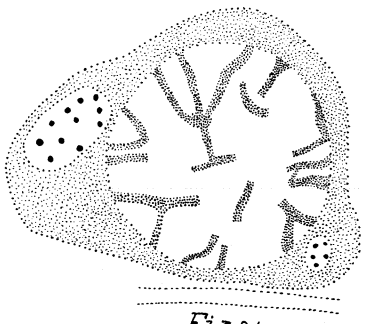

Fig. 26.

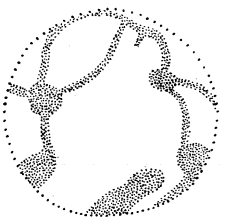

Fig. 27.

Fig. 30.

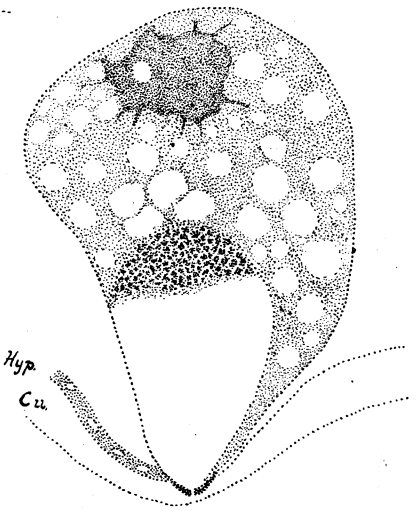

Fig. 29.

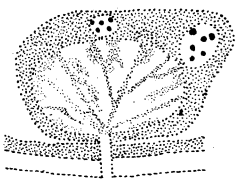

Fig. 28.

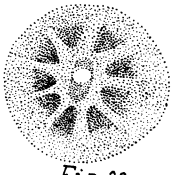

Fig. 32.

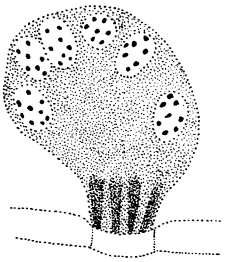

Fig. 31.

WISCONSIN HERPETOLOGICAL NOTES

T. E. B. POPE[1]

Quite recently there has been discovered in the reference library of the Milwaukee Museum a series of articles prepared by I. A. Lapham of Milwaukee, published in 1852, entitled "Fauna and Flora of Wisconsin"[2] that includes a list of twenty species of reptiles and amphibians that have been "actually observed" by him or "communicated" to him by "competent persons". This list of Wisconsin reptiles and amphibians, brief though it is, antedates the more extensive list of Dr. P. R. Hoy[3] by thirty-one years and extends our published record of many species backwards for seventy-seven years. The nomenclature employed at that time for the various species differs greatly from that now adopted. For instance, of the sixteen genera shown in Lapham's list only four have remained unchanged, viz: *Crotalus, Diadolphis, Storeria* and *Rana.* Specific names appear to have survived the years much better than the generic for thirteen out of the twenty are still in use. Only five species have the entire name—both generic and specific terms—unchanged, viz: *Diadophis punctatus, Storeria dekayi, Storeria occipitomaculata, Rana palustris* and *Rana sylvatica.* The list of the birds of the state was prepared by Dr. Hoy with asterisks indicating those species known to nest within the state. In the list of the mammals prepared by Dr. Lapham, the asterisks preceding certain species indicate, according to a footnote on page 337, that "The specimens of the species marked thus are preserved in the collection of the Nat. Hist. Association, at Madison." No explanation, however, appears for the asterisks preceding the names of eleven species of reptiles and amphibians and it is therefore assumed that such specimens, if they existed, were preserved like the mammals at Madison. As to the record of localities for the twenty species of reptiles and

[1] Curator of Lower Zoology, Milwaukee Public Museum.
[2] Trans. Wis. State Agri. Soc., Vol. II, pp. 337–434, 1852.
[3] "Catalogue of the Cold-blooded Vertebrates of Wisconsin", Geology of Wisconsin, Vol. 1, pp. 422–426, 1883.

amphibians listed by Lapham, it appears that 6 species were collected or observed at Racine, 10 at Milwaukee, 1 in Grant County and 3 with no locality given. It is known that Dr. Hoy donated many specimens to the U. S. National Museum at Washington and in all probability some of these six species provide the basis for the records of Wisconsin fauna from Racine County in the possession of that Museum as shown by the recent bulletin of the Milwaukee Museum, "The Amphibians and Reptiles of Wisconsin".[4] A review of the cataloged specimens from Wisconsin in the possession of the U. S. National Museum, according to Cope, for both the amphibia[5] and the reptiles[6] shows that such specimens were largely contributed by Prof. S. F. Baird and Dr. P. R. Hoy. Both appear to have donated about an equal number of specimens. The name of Dr. Lapham, however, does not appear. As to the remaining species no definite knowledge is available as to whether the records of Lapham were originally supported by actual specimens or only observational in character. Neither the Milwaukee Museum nor the University of Wisconsin has specimens of the Banded Rattlesnake *(Crotalus horridus)* from Grant County, yet Lapham has this serpent listed from the locality as *Crotalus durissus* and precedes the name with an asterisk. Again, he lists the Common Water Snake as *Nerodia sipedon* from Milwaukee, preceding the name with an asterisk. The specimens of this species in the Milwaukee Museum from Milwaukee County do not include any specimens either donated by Dr. Lapham or collected prior to the year 1900. Finally, as to the Ring-necked Snake *(Diadophis punctatus)* listed as from Milwaukee, but with no asterisk preceding the name, the Milwaukee Museum has no specimens in its collection from such a locality received at such an early date. Other examples of like nature could be cited to sustain the belief that the species listed by Lapham in this paper, exclusive of the items marked as Racine, were not supported by specimens. If, however, some or all of these fourteen species were so tangibly evidenced where are the specimens?

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[4] Pope, T. E. B. and Dickinson, W. E., Bull. Publ. Mus., Milw., Vol. 8, No. 1, 1928.

[5] Cope, E. D., "The Batrachia of North America", U. S. Nat. Mus., Bull. 34, 1889.

[6] Cope, E. D., "The Crocodilians, Lizards, and Snakes of North America", U. S. Nat. Mus. Rept. for 1898, Wash. D. C., 1900.

It is not the intention of the writer to analyze too rigidly this intensely interesting list of Lapham's, but instead to mention and refer to it only as partial evidence of the following list of additional distributional data on Wisconsin amphibians and reptiles accumulated since the publication of the Milwaukee Museum bulletin on the herpetology of the state. In like manner certain published records of cataloged specimens deposited in the U. S. National Museum must be cited, records that were not included in the list of specimens in the possession of that institution provided by Dr. Stejneger and which furnished the basis of the National Museum records mentioned in the Milwaukee Museum bulletin. A few items of species reported by F. J. W. Schmidt of the Field Museum in "Copeia"[7] that were inadvertently omitted from the same bulletin should be referred to.

The following species of Wisconsin amphibians and reptiles are hereby reported from counties not indicated in "The Amphibians and Reptiles of Wisconsin" and which are believed to constitute new distributional data:

A. Species that are represented by actual preserved specimens in the possession of institutions.

AMPHIBIA

Spotted Salamander *(Ambystoma maculatum).*
Fond du Lac County. Milwaukee Museum. Cat. No. 2249.
Collected by Towne L. Miller at Fairwater, Sept. 1928.

Four-toed Salamander *(Hemidactylium scutatum).*
Vernon County. Milwaukee Museum. Cat. No. 2301.
Collected by W. R. Spellum near Viroqua, Sept. 30, 1928.

American Toad *(Bufo americanus).*
Vernon County. Milwaukee Museum. Cat. No. 2272.
Collected by W. R. Spellum at Viroqua. Summer 1928.

Cricket Frog *(Acris gryllus).*
Vernon County. Milwaukee Museum. Cat. Nos. 2298–2299 (2 spec.).
Collected by W. R. Spellum at Viroqua. Summer 1928.

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[7] "Amphibians and Reptiles of Worden, Clark County, Wisconsin", Copeia, No. 154, pp. 129–132, 1926. (This article also includes a few species reported from Chippewa County.)

Swamp Tree Frog *(Pseudacris triseriata).*
Washington County. Milwaukee Museum. Cat. No. 2302.
Collected by W. E. Dickinson at Lake Amy Belle. July 25, 1927.
Racine County. U. S. National Museum. Cat. No. 3859 (7 spec.).
Received from Dr. P. R. Hoy.[8]

Green Frog *(Rana clamitans).*
Vernon County. Milwaukee Museum. Cat. Nos. 2267–2270 (4 spec.).
Collected by W. R. Spellum at Viroqua. Summer 1928.

Pickerel Frog *(Rana palustris).*
Vernon County. Milwaukee Museum. Cat. No. 2296.
Collected by W. R. Spellum at Viroqua. Summer 1928.
Chippewa County. Field Museum. Cat. Nos. 8230–8236 (7 spec.).
Collected by F. J. W. Schmidt at mouth of Yellow River, Lake Wissota, Anson Township.[9]

REPTILIA

Northern Skink *(Eumeces septentrionalis).*
Chippewa County. Field Museum. Cat. No. 5515.
Collected by W. E. Slagg at Chippewa Falls.[10]

Blue Racer *(Coluber constrictor flaviventris).*
Trempealeau County. Milwaukee Museum. Cat. No. 2230.
Collected by Lewis Dartt during museum expedition. June 1928.

Queen Snake *(Natrix septemvittata).*
Ozaukee County. Milwaukee Museum. Cat. No. 2225.
Collected by Neil A. Euting at Cedarburg on May 1, 1928.
Received alive and killed ten days later at Museum.

Common Water Snake *(Natrix sipedon sipedon).*
Racine County. U. S. National Museum. Cat. No. 1072 (2 spec.).
Collected in 1853 by Prof. S. F. Baird.[11]

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[8] Cope, E. D., "The Batrachia of North America", Op. Cit., p. 343 *(Chorophilus triseriatus).*
[9] "Copeia", Op. Cit., p. 132.
[10] Ibid., p. 132.
[11] Cope, E. D., "The Crocodilians, Lizards, and Snakes of North America", Op. Cit., p. 971 *(Natrix fasciata sipedon).*

De Kay's Snake *(Storeria dekayi).*
Racine County. U. S. National Museum. Cat. No. 1858 (2 spec.).
Received from Dr. P. R. Hoy of Racine.[12]

Red-bellied Snake *(Storeria occipitomaculata).*
Racine County. U. S. National Museum. Cat. No. 7281.
Received from Dr. P. R. Hoy of Racine.[13]

Common Garter Snake *(Thamnophis sirtalis sirtalis).*
Lincoln County. Milwaukee Museum. Cat. No. 2313.
Collected by W. E. Dickinson on Aug. 5, 1928.

Massasauga *(Sistrurus catenatus catenatus).*
Walworth County. Milwaukee Museum. Cat. No. 2247.
Collected by R. L. Cobb on Aug. 4, 1928. Milwaukee Museum, Cat. 2257.
Collected by Miss Mary Bray at Richmond. Sept. 1928.

Western Diamond-back Rattlesnake *(Crotalus atrox atrox).*
Vernon County. Milwaukee Museum. Cat. No. 2293.
Received from W. R. Spellum. Killed near Viroqua on June 12, 1928.

Banded Rattlesnake *(Crotalus horridus).*
Trempealeau County. Milwaukee Museum. Cat. No. 2231.
Collected by Towne L. Miller at Mt. Brady on June 10, 1928.

Wood Turtle *(Clemmys insculpta).*
Vernon County. Milwaukee Museum. Cat. No. 2291. (Shell of).
Collected by W. R. Spellum at Bad Axe River on July 26, 1928.

Blanding's Turtle (Emys blandingii).
Trempealeau County. Milwaukee Museum. Cat. No. 2245.
Collected by Towne L. Miller during museum expedition. June 1928.

Map Turtle *(Graptemys geographica).*
Trempealeau County. Milwaukee Museum. Cat. Nos. 2235–2237.
Collected by Towne L. Miller during museum expedition. June 1928.

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[12] Ibid., p. 1002.
[13] Ibid., p. 1005.

Spiny Soft-shelled Turtle (Amyda spinifera).
Trempealeau County. Milwaukee Museum. Cat. No. 2234.
Collected by Towne L. Miller during museum expedition. June 1928.
Vernon County. Milwaukee Museum. Cat. No. 2279.
Collected by W. R. Spellum near Viroqua. Summer 1928.

B. Species that are listed or mentioned in recognized scientific publications.

AMPHIBIA

Red-backed Salamander *(Plethodon cinereus).*
Clark County. Reported by F. J. W. Schmidt. "Copeia", No. 154, p. 132.
Pickerel Frog *(Rana palustris).*
Milwaukee County. Reported by I. A. Lapham. "Fauna and Flora of Wisconsin", Trans. Wis. State Agri. Soc., 1852, p. 366.

REPTILIA

Hog-nosed Snake *(Heterodon contortrix).*
Clark County. Reported by F. J. W. Schmidt. "Copeia", No. 154, p. 132.
Blue Racer *(Coluber constrictor flaviventris).*
Milwaukee County. Reported by I. A. Lapham. "Fauna and Flora of Wisconsin", Trans. Wis. State Agri. Soc., 1852, p. 365, as *Bascanion constrictor.*

C. Species that have been observed by reliable persons.

AMPHIBIA

Mudpuppy *(Necturus maculosus).*
Green Lake County. A specimen was caught by hook and line by Neil A. Euting at Princeton Locks on May 21, 1928.
American Toad *(Bufo americanus).*
Florence County. Observed by W. E. Dickinson at Long Lake on July 7, 1928.

Leopard Frog *(Rana pipiens).*
Forest County, observed by W. E. Dickinson at Rat River on July 7, 1928.
Mink Frog *(Rana septentrionalis).*
Florence County. Observed by W. E. Dickinson at Tomahawk River on Aug. 5, 1928.

REPTILIA

Hog-nosed Snake *(Heterodon contortrix).*
Trempealeau County. Reported by Towne L. Miller during museum expedition on April 16, 1928.
Smooth Green Snake *(Liopeltis vernalis).*
Winnebago County. Mr. R. N. Buckstaff of the Oshkosh Museum had a living specimen that he collected at Fisk in 1916.
Green Lake and Fond du Lac counties. Reported by Towne L. Miller on April 16, 1928.
Marquette County. Reported by Towne L. Miller in summer of 1928.
Blue Racer *(Coluber constrictor flaviventris).*
Marquette County. Reported by Towne L. Miller in letter of April 24, 1928 that one was killed in Packwaukee Township near the Fox River. Length 50 inches.
Bull Snake *(Pituophis sayi).*
Trempealeau County. Reported by Towne L. Miller in letters of June 11 and June 15, 1928. Two specimens caught, one released and the other escaped.
Shawano County. Observed by W. E. Dickinson on road July 3, 1928.
Forest County. Observed by W. E. Dickinson at Pickerel Lake on July 5, 1928.
Common Water Snake *(Natrix sipedon sipedon).*
Green Lake County. Observed by W. E. Dickinson at Green Lake on Aug. 7, 1928.
De Kay's Snake *(Storeria dekayi).*
Green Lake County. Observed by W. E. Dickinson at Green Lake on Aug. 7, 1928.
Red-bellied Snake *(Storeria occipitomaculata).*
Waupaca County. Captured by Charles Koch on May 15, 1927 and held in confinement at the Oshkosh Museum on May 24, 1927 when the writer visited that institution.
Shawano County. Observed by R. N. Buckstaff in 1927.

Common Garter Snake *(Thamnophis sirtalis sirtalis).*

Winnebago County. A living specimen, captured by museum employees within the county, was held in captivity at the Oshkosh Museum on May 24, 1927 when the writer visited that institution.

Florence County. Observed by W. E. Dickinson at Tipler on July 6, 1928.

Jefferson County. Observed by W. E. Dickinson near Jefferson on July 18, 1928.

Green Lake County. Observed by W. E. Dickinson at Green Lake on Aug. 7, 1928.

Waupaca County. Observed by W. E. Dickinson at Weyauwega on Aug. 20, 1928.

Snapping Turtle *(Chelydra serpentina).*

Green Lake County. Captured by Towne L. Miller, George L. Pasco and Edward Steinbring at Dakin Creek. Reported by Mr. Miller in letter of April 24, 1928 and supported by photograph. A very large specimen with carapace about 20 inches long.

Chippewa County. Observed by W. E. Dickinson near Chippewa Falls on July 31, 1928.

Marquette County. Observed by Towne L. Miller. Summer 1928.

Waupaca County. Observed by W. E. Dickinson at Weyauwega on Aug. 20, 1928.

Blanding's Turtle *(Emys blandingii).*

Rock County. Observed by W. E. Dickinson in Western part of county at some distance from Brodhead on July 18, 1928.

Western Painted Turtle *(Chrysemys marginata marginata).*

Shawano County. Observed by W. E. Dickinson at Keshena on July 3, 1928.

Green Lake County. Observed by W. E. Dickinson at Green Lake on Aug. 7, 1928.

Bell's Turtle *(Chrysemys marginata bellii).*

Ozaukee County. Observed by W. E. Dickinson near Waubeka on June 27, 1928.

Jefferson County. Observed by W. E. Dickinson near Jefferson on July 18, 1928.

Green Lake County. Observed by W. E. Dickinson at Green Lake on Aug. 7, 1928.

Spiny Soft-shelled Turtle *(Amyda spinifera)*.

La Crosse County. Collected by Gilbert Raasch and Roy G. Blank at West Salem in September 1928. Specimen released. See Milwaukee Museum photograph No. 139202.

Special mention may now be made of certain species acquired by the Milwaukee Museum, as shown, that represent new localities, are rather uncommon, or are entirely new additions to the state fauna.

Four-toed Salamander *(Hemidactylium scutatum)*. Heretofore the record for this interesting little salamander shows that the species has only been recorded as from the eastern part of the state (Racine and Winnebago counties). Mr. W. R. Spellum of Viroqua now reports it as "common and widely spread over Vernon County", according to several letters received in the fall of 1928. He states that he had at least ten living specimens at one time confined in a fish globe and all were doing finely, active and healthy up to his last report on Dec. 15, 1928.

Glass Snake *(Ophisaurus ventralis)*. It is of interest to mention the reoccurrence of this species in Marquette County. In early December of 1928 the Milwaukee Museum received a fine preserved specimen (Cat. No. 2258) from Dr. George Bush of Ripon that was collected in September of that year. This limbless lizard, last reported by Prof. Wagner from the same county in 1922,[14] still remains as one of the 'uncommon' reptiles of the state.

Massasauga *(Sistrurus catenatus catenatus)*. Walworth County is now definitely added to the few southern counties of the state as a habitat for the Massasauga as shown by the two specimens recently deposited in the Milwaukee Museum during the last year. Fully a dozen specimens were also captured in Columbia County by Mr. Ray Weldon of Portage in the summer of 1928. Heretofore our earliest record for this species appeared to be the two specimens (Cat. No. 525) deposited in the U. S. National Museum by Dr. Hoy from Racine in about 1858, but now we note that Lapham in his list of 1852 includes this serpent from the same locality.

Western Diamond-back Rattlesnake *(Crotalus atrox atrox)*.

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[14] Wagner, G., "On the Present Status of Ophisaurus in Wisconsin", Copeia, No. 113, pp. 90–91, 1922.

The presence of this species in the state of Wisconsin is supported by Milwaukee Museum cataloged specimen No. 2293 which consists of a finely preserved head and tail in formaldehyde and the dried skin of the body. This specimen was obtained from Mr. W. R. Spellum on September 20, 1928. He had purchased the snake about three hours after its death from an Italian who had killed it on the morning of June 12, 1928 in a quarry on Highway No. 56 about five miles west of Viroqua. The Italian was a workman employed by the Nelson, Mullen & Nelson Company, road contractors engaged in resurfacing the highway, and had brought the reptile into Viroqua in order to collect the bounty offered by that county for rattlesnakes. Mr. Spellum, who for some time had maintained the existence of this species of diamond-backed rattlesnake in Vernon County and who was always on the watch for positive evidence to support his assertion, purchased the snake from the Italian workman. Mr. Spellum affirms that the body of the snake was not spoiled, that the flesh had hardly lost its heat, that only the head had been crushed in the killing but this he had pressed back into its original condition as best he could. Immediately after purchasing the snake he had photographed it with a kodak, made an excellent plaster mold of the entire reptile (Milwaukee Museum Mold No. 367), cut off the head and tail, which he preserved, and finally stripped off the skin and dried it. The head and tail were cut off and the skin dried because he did not have a container large enough or preservative sufficient for the entire specimen in toto. The length of the snake from the tip of the head to the base of the tail, measured from the plaster mold, was four feet and nine inches; the total length to the end of the rattle was four feet and ten and a half inches. Furthermore in order to dispel any doubts as to the presence of this species within the state, it may be stated that about two and a half months later, three more of these Western Diamond-back Rattlesnakes were killed on the Hogback Hill on U. S. Highway No. 61 about seven miles south of Viroqua. This lot of snakes, one individual of which was said to be a young one, was killed by workmen or by the steam shovel engaged in road construction. An affidavit, signed by Mr. Emil Berg, Superintendent of Construction for the Grant Construction Company, to this effect is in possession of the writer. In this affidavit Mr. Berg affirms that he is well acquainted with

the differences between the Banded and Diamond-back Rattlesnakes. Mr. Spellum states that he saw the tails of these three snakes which were presented for bounty and of course destroyed. Thus it appears that the Texas or Western Diamond-back Rattlesnake has actually been killed in two places near Viroqua—one specimen, herewith produced, killed in the early summer to the west of the city and three others, supported by an affidavit, killed in the latter part of the summer much farther to the south. This evidence has followed a long period of suspicion as to the existence of the species in the southwestern part of the state and which was caused by the many rumors that came to the attention of the writer. Until the fall of 1928, however, these rumors could not be verified. Evidently the Western Diamond-back Rattlesnake has been established in the state for a number of years, perhaps much longer than we realize. Mr. Spellum has prepared a list of six residents of Viroqua County and vicinity who have affirmed that they have seen or killed this southern rattlesnake and all of whom are well acquainted with the appearance of the common Banded Rattlesnake *(Crotalus horridus)*, with which form the southern species has probably been confused. It may be stated further that the writer heard rumors as to the killing of this species of reptile several years ago from Grant County, and, according to Mr. Charles E. Brown of Madison, it is said that the late Colonel Anderson of that city had remarked that "Isolated instances of Diamond-backs had been reported along the Mississippi River but that he had not been able to secure specimens."

How the Western Diamond-back Rattlesnake found its way into Wisconsin we do not know at this writing but it is quite probable that it came up the Mississippi River on either the Illinois or Iowa side. This river offers an excellent and easy means of entrance into the state. This fact is recognized by Prof. Wagner in his article on the "Status of Ophisaurus in Wisconsin", when, commenting on the presence of that lizard in Marquette County, he remarks, "There is evidence that this stream (Wisconsin River) and other tributaries of the Mississippi have been the highways of invasion for a number of species of more southern vertebrates into Wisconsin."[15] However that may be, we do have many instances of both plants and

[15] Ibid., p. 91.

animals that have entered and established themselves successfully in the state-forms that formerly were only known from far southern regions. Mr. Frank E. Ellis of Maquoketa, Iowa, a collector of local note, writes in a recent letter, "Some of the natural southern live things have in recent years migrated to Iowa and seem to be doing fine, at least in this community. For instance, the opossum has become recently very plentiful. The Cardinal Grosbeak has become about as common here as robins. For the last eight years a nice community of real southern, and I might add eastern mocking bird, has been established about four miles out in the country." There is thus observed a plain case of parallelism between reptiles and other branches of vertebrates in this respect. Again, the topography of Vernon County and vicinity, as a result of geological conditions, offers a very favorable habitat for rattlesnakes.

Wood Turtle *(Clemmys insculpta)*. The finding of a fine living specimen of this species at the Bad Axe River in Vernon County on July 26, 1928 by Mr. W. R. Spellum supports the belief that this uncommon turtle is widely distributed over the state, even though it is not frequently recognized or collected. Heretofore our record shows it to be found in the northwestern, central and eastern counties. This capture represents a southwestern locality. Mr. Spellum reports that this specimen was a female containing twenty-one eggs and that the flesh was of a yellow color similar to that of the plastron. This capture is now evidenced by a complete, perfect shell, Milwaukee Museum Cat. No. 2291.

A SECOND REPORT ON SOLAR RADIATION AND INLAND LAKES

E. A. BIRGE AND C. JUDAY

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

CONTENTS

Introduction ---------- 285–290
Apparatus ---------- 286
Methods and computations ---------- 288
Typical transmission curves from six lakes ---------- 290–302
Table 1, characteristics of lakes ---------- 291
Table 2, behavior toward light ---------- 292
Discussion of curves ---------- 294
Comparison of lakes ---------- 294
Intermediate region and "average transmission" ---------- 297
Variations of average ---------- 298
General statement ---------- 300
Observations of 1929 compared with those of earlier years ---------- 302–306
Table 3, statistics of lakes ---------- 305
Table 4, classification of lakes by transmission ---------- 305
Comparison of southeastern and northeastern lakes ---------- 306
Transmission through light filters ---------- 307–334
Methods ---------- 307
Characters of light filters used ---------- 308
Table 5, statistics of light filters ---------- 308
Table 6. limits of spectral colors ---------- 308
Light filters and solar energy spectrum ---------- 310
Table 7, per cent of energy transmitted by filters ---------- 310
Changes in energy spectrum ---------- 311
Observations and time required for them ---------- 312
Data ---------- 313
Object and limitations of study ---------- 314
Transmission in upper meter ---------- 314
Results—general ---------- 315–317
Table 8, transmission of total and of colors ---------- 315
Behavior of the several filters ---------- 317–321
Total and colored radiation in the lakes ---------- 321–327
Comparison of total and the several colors ---------- 327
Table 9, transmission of colors and that of total ---------- 327
Transmission in single lakes ---------- 327–333
Conclusion ---------- 333
Literature cited ---------- 334

Introduction

This paper deals with solar radiation delivered to a unit of horizontal surface at various depths in the lakes of the Highland Lake District of Northeastern Wisconsin. It continues and enlarges the subject reported upon in an earlier paper (Birge and Juday, '29). The present paper consists of three sections:

1. Typical transmission curves.
2. Observations of 1929 compared with those of earlier years.
3. Transmission of radiation which has passed through light filters.

Most of the work of 1929 was given to the last section of this report—a preliminary study of the transmission in lakes of radiation passed through light filters. As large a number of series of observations as practicable was obtained in order to cover the range of variation in the lakes. Altogether 47 series were made in 36 different lakes, besides numerous experimental readings. The work was favored by the weather of the summer; observations were made on 29 days between June 28 and August 29; and there were two or three other days on which this work would have been possible. Thus about one-half of the days were favorable; a much larger number than was found in 1928. The necessity of securing a large number of series led us to begin observing at an earlier hour of the day than had been our custom in former years. We began as early as 9 a. m. or even at 8:30, while before we did not start work before 9:30 or 10 a. m. This fact has made the value of cos r as low as 0.85 or even less in extreme cases.

The pyrlimnometer used in 1929 was a new instrument. Its thermal element is a large surface Moll thermopile made by Kipp and Sons, of Delft, Holland. With this thermopile and with the most sensitive millivoltmeter, radiation can be followed until it is reduced to about 0.1 per cent of its value at the surface, in much the same way that earlier instruments followed it to 1.0 per cent. The mounting of the thermopile is also new and is illustrated in fig. 1, which may be compared with the figure of the former apparatus shown in Birge '22, pl. 39, figs. 3, 4. The main difference in the mounting is in the shutter or carrier of the light filters. In the present pyrlimnometer this

is a brass plate, about 18 cm. in diameter, having five large openings which may be left open or may hold opaque discs or light filters. The shutter rotates on its axis and is operated by

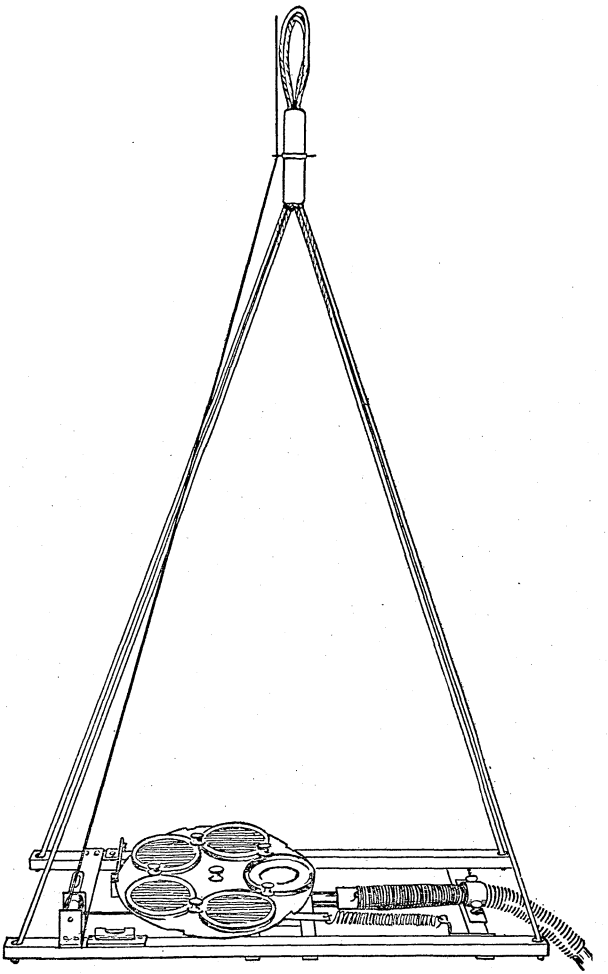

FIG. 1. Pyrlimnometer, pattern of 1929. The Moll thermopile is seen in the free opening of the shutter. The next opening of the shutter, that at the back of the figure, carries the opaque disc; the following openings carry the blue, red. and yellow light filters. The operating cord is seen; a pull on this will revolve the shutter and bring the opaque disc above the thermopile. The catch of the shutter is seen at the left, and in the edge of the shutter are seen the notches by which it is stopped and held in place when moved forward. Diameter of shutter, 18 cm.; length of frame 50 cm.

one cord. When this is pulled the shutter is released and moves forward through one-fifth of a revolution; it is then stopped and fixed in place with the center of the new opening or light filter over the center of the thermopile. The detailed description of the instrument is deferred to a later paper, since it is proposed to change some of its details before the season of 1930. Probably a new shutter will be installed, carrying a larger number of openings for light filters, etc. In its present construction the apparatus was wholly satisfactory during the summer of 1929. It was regularly operated by two persons: Mr. Birge handled the thermopile and Mr. H. C. Baum read and recorded the millivoltmeter.

In this paper nothing is said about the quantity of energy recorded either in the total radiation or in the several colors. In the discussion of total radiation in sections 1 and 2 of the paper, energy is recorded as a percentage of that delivered to the surface. This is the base for computation and is placed as equal to 100 per cent. In section 3, which deals with the colors, the base is the radiation present at the depth of one meter below the surface. This matter is further discussed on p. 314.

Little use is made in this paper of the percentile values, which can always be seen in the diagrams. The main interest of the paper turns on the transmission of radiation through the water of the lake. The term *transmission* is employed as in our former paper (Birge and Juday, '29, p. 511). As the radiation from the sun penetrates the water of lakes part is converted into other forms of energy and part goes on as radiation. Transmission refers to the rate of change in the quantity of energy which thus continues on its way. If the rate of change is small transmission is *high;* in the opposite case it is *low.* When transmission is given a numerical value the term relates to the passage of radiation through a stratum of water of standard thickness—in this paper, one meter. The number assigned to transmission is the ratio between the swings of the needle of the millivoltmeter when the thermopile is exposed first to radiation at the upper surface of the meter stratum and then exposed at its lower level. If the swing of the millivoltmeter for a reading at 2 m. below the surface is 38 divisions of the scale and is 26 divisions when read at 3 m., the transmission thus indicated is 26/38 or 68.4. This result is the *observed*

transmission which must be reduced to transmission at zenith sun for final use in the paper.

The methods of handling the observations are essentially similar to those reported in our former paper (pp. 514–520), with one exception, which is noted below. They may be summarized as follows:

1. All observations are made in direct sunlight and all radiation is treated as direct, not as diffuse.

2. Corrections for the glass cover of the thermopile are the same as those used before (p. 515).

3. The value of the cosine of the angle of refraction of the direct radiation is computed for the mean altitude of the sun during the observations.

4. All observations are adjusted for zenith sun, as in the former paper (p. 517); but the method of computation is different. The method of adjustment reported in that paper is evidently approximate, but was sufficiently close for the depths of water and the quantities of radiation handled in that paper. The method is not applicable to data from complete series in lakes with marked decrease of radiation near the bottom. The method of adjustment employed in the present paper depends on a formula which was worked out for us by Professor H. W. March, of the department of mathematics, University of Wisconsin. This is another instance of the efficient help that he has given to us. The formula is as follows:

$$\text{Log } a_1 = \log A - \cos r \ (\log A - \log a)$$

In this formula, A = base of computation; in this case taken as 100 per cent.

a = per cent observed at any given depth.
a_1 = per cent adjusted for zenith sun.
cos r = cosine of angle of refraction of direct rays of sun, corresponding to altitude of sun at time of observation.

In practice this computation is worked out graphically for the most part. The per cent observed at any depth is platted on semi-logarithmic paper; the distance in millimeters is measured from this point to the line indicating 100 per cent; this number is multiplied by cos r; the product is the distance in millimeters on the same coordinate paper from the line of 100 per cent to

the per cent adjusted for zenith sun. All observations in the present paper have been adjusted in this way.

The two methods give identical results when the transmission is uniform from meter to meter, as in the middle portion of energy curves. Where the transmission is increasing rapidly the new method yields a higher corrected per cent; where transmission is rapidly decreasing the results are lower. The practical difference between the two methods in the cases reported from our lakes is that the per cent of total radiation found at one meter depth may be raised from 1 to 3 points; the value of the mean transmission below is slightly raised, but so far as noted not so much as one per cent. Such differences in transmission lie within the range of variation to be expected in any lake from day to day and even from hour to hour. There is no reason for recomputing the data of our former paper; they may be compared directly with those of the present paper.

At the bottom of the lake the case is otherwise, since the differences between the methods increase with depth at which the decrease in transmission is found. The extension of observations to this region called attention to the necessity for a change of method.

1. TYPICAL TRANSMISSION CURVES

The observations reported in our earlier paper (Birge and Juday, '29) showed the transmission of solar radiation in the surface meter and in those immediately below, to a maximum depth of 10 m. and to a minimum amount of one per cent of the radiation incident on the surface. These results, therefore, indicated the transmission through the surface stratum and through the whole or part of that middle region of a lake where transmission is approximately uniform from meter to meter. They did not extend far enough to show the transmission in the hypolimnion and especially the changes in transmission near the bottom of the lake, due to accumulating suspended material or seston[1] in the water and to increasing color. This informa-

[1] The term *seston* was introduced by Kolkwitz in 1912 as a name for that particulate material which can be removed from water by a net or sieve. It was extended by Naumann in 1924 to cover all such material suspended in the water, whether removable by net, by centrifuge, or by filter. It includes plankton, organic debris, and non-living particles, such as fine grains of silt. Its presence produces *turbidity* in water.

tion can now be supplied for six lakes, ranging in depth from 8.5 m. to 20 m., in which observations extended to the bottom or to within about a meter of the full depth.

The main facts relating to these lakes and to the observations on them are summarized in tables 1 and 2.

TABLE 1. *Characteristics of lakes whose complete transmission curves are shown*

1	2	3	4	5 Color		6	7	8	9	10	11
Lake	L'gth km.	Area ha.	Max. depth m.	Surf.	Bot.	Cond.	Trp. m.	Epi-limnion	Plkn. p.p.m.	Org. C p.p.m.	CO_2 p.p.m.
Crystal	1.00	37	21.0	0	Tr.	9.4	12.2	9.0	0.37	1.70	1.75
Day	1.22	52	16.0	b	27	12.3	9.2	5.5	0.58	3.22	1.25
Diamond	1.12	31	11.5	0	16	12.5	10.5	8.0	0.37	1.24	1.00
Finley	0.93	60	8.5	0	10	13.3	6.1	6.0	0.81	4.62	2.50
Hillis	0.30	9	9.0	b	35	13.0	6.9	6.0	0.65	2.62	0.75
Weber	0.66	15	14.1	0	8	9.3	10.7	7.5	1.13	2.54	1.75

NOTES

Col. 2. Hillis Lake is not surveyed; length is estimated.

Col. 5. Color is measured on the U. S. G. S. or platinum cobalt scale. Tr. = trace; b = less than 8.

Col. 6. Conductivity is stated in reciprocal megohms of resistance.

Col. 7. Trp. gives the transparency; that is, the depth at which Secchi's disc, 20 cm. in diameter, disappears.

Col. 8. This gives the thickness of the epilimnion in meters. The bottom of the epilimnion lies in the meter or half-meter below the depth stated.

Col. 9. This gives the weight in milligrams of the dry organic matter in the centrifuge plankton from one liter of water.

Col. 10. This gives the weight in milligrams of the dry organic carbon in the dry residue from one liter of water. The total organic matter in the residue is about 2.1 times the carbon.

Col. 11. This CO_2 is that in combination with the carbonates, chiefly calcium and magnesium.

Cols. 6, 9, 10 and 11 refer to the surface water.

TABLE 2. *Transmission of the six lakes*

1	2	3	4	5	6	7		8
Lake	Date	Hour	Depth	Cos r	% at 1 m.	Mean % trans.	Meters	1% at m.
Crystal	vii , 23	11:15-12:30	19	90	34	83	1–15	18.3
Day	viii, 26	1:45- 2:15	15	86	32	75	1–10	12.0
Diamond	vii , 25	9:00- 9:45	11	85	33	85	2- 9	12.5
Finley	vii , 19	11:35-12:20	8	95	29	69	1- 6	7.4
Hillis	vii ,'16	2:40- 3:30	8	88	35	70	1- 5	7.7
Weber	viii,'23	2:00- 3:06	14	83	36	75	1–11	13.1

Col. 4. This gives the depth to which reading extended.

Col. 5. This gives the value of the cosine of the angle of refraction, used in adjusting for zenith sun.

Col. 6. This gives the per cent of incident radiation which was found at the depth of one meter.

Col. 7. This gives the average per cent of transmission in the intermediate region and the extent of that region. See pp. 296–299.

Col. 8. This gives the depth at which was found one per cent of the radiation incident on the surface of the lake. In the case of Diamond Lake this is computed, as the depth is below the bottom of the lake.

Table 1 shows that all of these lakes contain very soft water, as is indicated both by the low conductivity and the fixed carbon dioxid. The former shows the effect of the total electrolytes, whose quantity may be roughly estimated at the number of milligrams per liter equal to three-fourths of the number indicating the conductivity. The fixed carbon dioxid is mainly determined by the amount of calcium and magnesium carbonate in solution. The lakes belong to a type very frequent in this district, although apparently not common elsewhere. They are lakes with neither inlet nor outlet, fed by the rain water falling on the lake and on its immediate environment. They lie in a sandy region, from which there is practically no run off from the surface in summer, so that all water which enters the lakes from the surroundings passes through a sand filter before reaching them. Such lakes contain an amount of dissolved solids far smaller than that contained in neighboring lakes which are fed by springs or affluents. The amount may be as small as one-tenth of that found in closely adjacent lakes of the other type. There is little organic matter in the water, whether as plankton cells, as particles of organic debris, or as dissolved organic material. The color is low, the surface water showing little or more commonly no stain due to extractive sub-

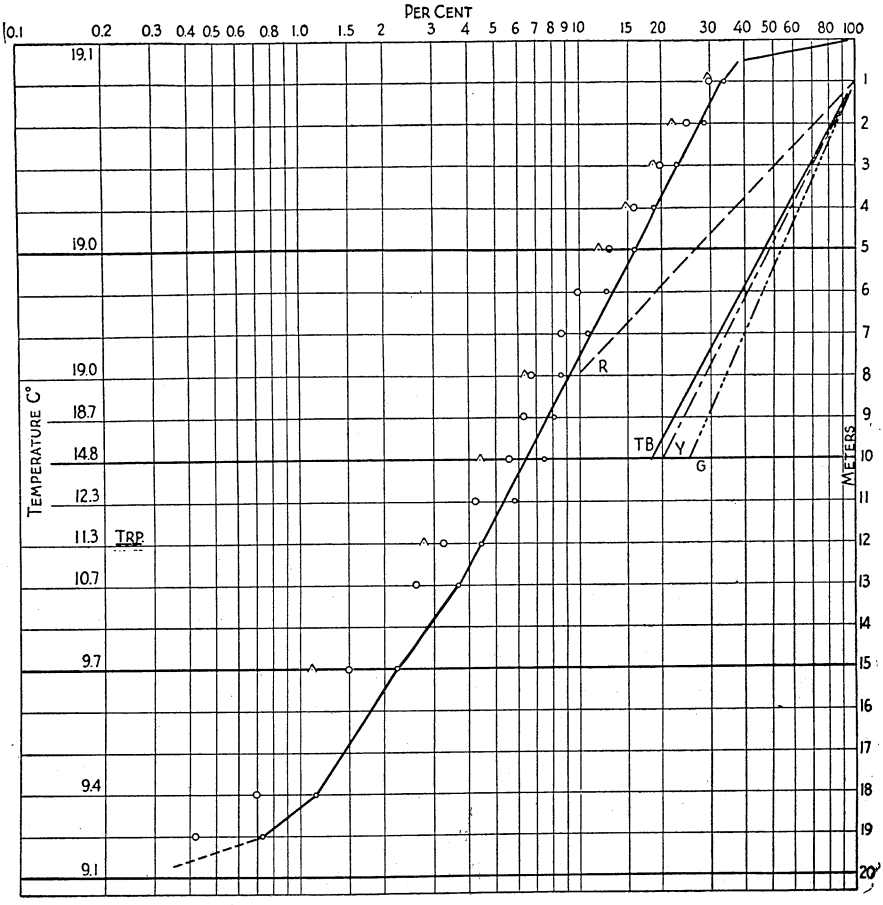

FIG. 2. Crystal Lake, Aug. 23, 1929. This is a "blue" lake, or perhaps, greenish blue; water free from stain as measured by the platinum-cobalt scale; plankton, small in quantity; transparency, great. Temperatures and transparency (Trp) are indicated on the left side of the diagram. Larger circles near main line indicate percentile value of the observed radiation, that received in air being 100; smaller circles indicate per cent with zenith sun. Dots covered with an inverted V indicate per cent observed on Aug. 7. Observations on Aug. 23 were limited by length of cable attached to pyrlimnometer; total depth was about 20 m. Note rise of transmission between 8 and 10 m. and subjacent fall to average. Note also slight decrease of transmission below 13 m. and rapid decrease below 18 m.

At the right side of the diagram are platted the mean transmission curves shown by radiation transmitted through light filters. For these the base or 100 per cent is the reading of total radiation and of each filter at the depth of one meter. Curves are not continued to full depth of observation, but are inserted to indicate relations of color curves with the main line of transmission in the several lakes. See discussion in part 3 of this paper; see also explanation of letters, fig. 12.

stances, but in most of the lakes the bottom water shows a marked color in the summer, quite great enough to affect transmission in that region.

The transmission curves for the six lakes are shown in figs. 2–7. Each curve when platted on semi-logarithmic paper, has the form of a sigmoid curve, the upper end being concave downward and the lower end concave upward. It should be noted that no attempt is made to show changes in transmission in the upper one-half meter of the water.

The upper end of the curve shows a low transmission which increases rapidly through the upper meter. This low transmission in the upper centimeters of the first meter is in large part due to the presence of infra-red and lower red radiation whose transmission in water is very small. As this part of the spectrum is absorbed, the transmission of the remainder—chiefly composed of the visible spectrum—rises rapidly. This effect is mainly due to the relation of radiation and water and is present in all lakes. A variable factor also frequently found in the upper meter is the presence there of a larger amount of seston than is found in the strata below.

The lower end of the curve shows a decreasing transmission, which depends mainly on obstruction to radiation offered by the increasing amount of seston as the bottom is neared, and also in some cases by the increased color of the water.

These two parts of the curve are connected by an intermediate region in which the average transmission is nearly uniform. This region begins at the depth of one or two meters below the surface—the exact depth in such lakes as these depending on the relative amount of seston in the upper water. It ends where the decrease of transmission becomes obvious in the deeper water. Its extent and its regularity are subject to great variation in the different lakes and also within each of the lakes. These matters will be discussed later, but at present it is enough to say that this region gives the general character to the transmission of the lake and to its biology, so far as this depends on the sun.

The transmission in the upper meter of these six lakes shows but little difference, the value of radiation at one meter ranging from 27 to 33 per cent of that delivered to the surface. This uniformity depends on the facts that the lakes have very transparent water and relatively little plankton. Thus the main

factor affecting the transmission in this stratum is the opacity of water to infra-red and red radiation. The transmission is accordingly high; but it may be noted that in 1929 no transmission found in the upper meter equalled those observed in earlier years. Crystal Lake, for instance, has been found to have

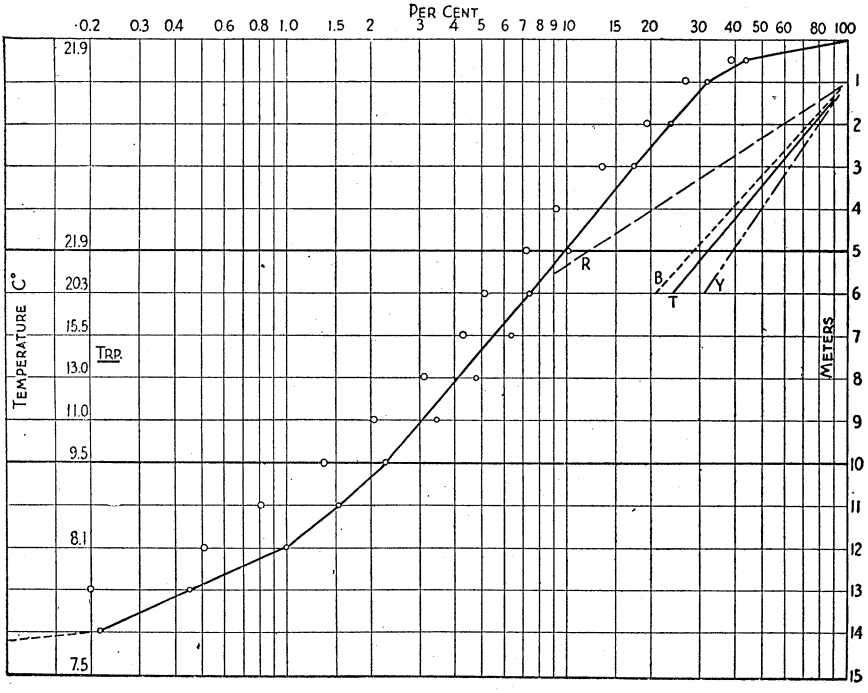

FIG. 3. Day Lake, Aug. 26, 1929. The color lines come from observations on July 29, when transparency was the same as on the later date. Note increased transmission below 6 m. with return to mean; rapid reduction of transmission below 10 m. The total depth was about 15.5 m. At 14 m. the index of the millivoltmeter moved about one division of the scale; at 15 m. there was a slight response, too small to measure. The color is recorded as "less than 8" at surface, and 27 at 15.5 m.; centrifuge plankton at surface 0.58 p.p.m. of dry organic matter; at 15.5 m. 1.61 p.p.m. Thus transmission in bottom water is checked both by color and by seston.

nearly or quite 40 per cent of incident radiation present at one meter (Birge and Juday, '29, p. 562). The lower transmission in 1929 was no doubt due to unusual rains in the earlier part of the summer, which raised the level of the water of the lakes above the sand margin and brought it into the grassy bank.

In only one of the six lakes, Diamond, (fig. 4), did the plankton in the 2–3 m. stratum offer a noticeably greater obstruction to radiation than was found in the meters immediately below.

Thus these lakes are much alike in the upper meter; below that stratum they differ and they fall into three groups of two lakes each. The average value of the transmission in the intermediate region of Finley Lake is 69 and is 70 in Hillis Lake.

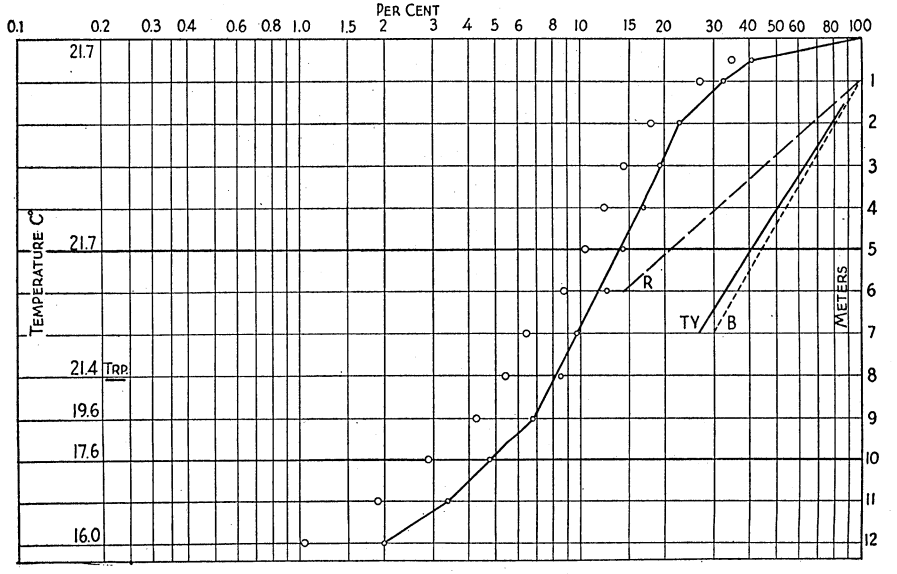

FIG. 4. Diamond Lake, July 25, 1929. This is a case of a small lake with very transparent water, and with a hypolimnion of small volume, which consequently has a considerable amount of seston. The dry organic matter in centrifuge plankton was 0.30 p.p.m. at surface and 0.93 p.p.m. at bottom; color was zero at surface and 16 at bottom. The lowest reading was about one-fourth meter above the bottom.

In Day and Weber lakes it is 74 and 75; and Crystal and Diamond lakes have respectively 83 and 85. Thus the first named lakes have a transmission not infrequently shown by lakes both in the northern and the southern parts of Wisconsin; it may commonly be found in almost any fairly deep oligotrophic lake and may be nearly reached by lakes with abundant plankton, like Lake Mendota, at times when the quantity of the plankton is relatively small. The transmission of Day and Weber lakes is higher than that shown by any southern lakes, except Devils, Marl, and Elkhart, and is only occasionally found in them.

Blue, Clear, and Star lakes in Northeastern Wisconsin are the only lakes outside of the present list whose transmission has been found to reach or approach 75, although there are other similar lakes yet to be visited. The transmission of the third pair of lakes—Crystal and Diamond—exceeds 80 and may reach or exceed 85. This is an average transmission attained by no southern lake and by very few in the north. In 1929 Clear Lake was the only other lake whose transmission exceeded 80. It should be noted that the maximum transmission found in 1929 was not as large as in other years. In 1926 Crystal Lake had a transmission approaching or reaching 90 in the region below 6 m. (Birge and Juday, '29, p. 559). The lower result in 1929 was probably due to the same cause as that which lowered the maximum per cent found at the depth of one meter—the excessive rains in the early summer.

These differences in average transmission in these lakes are to be attributed mainly to differences in the quantity of seston rather than to color, in which respect the lakes are much alike. Table 1 shows that the transparency of Hillis and Finley lakes is much less than that of the other lakes and this relative opacity is due to suspended material.

The transmission in the intermediate region is here described as uniform. The diagrams show that this uniformity is by no means exact. Accurate measurements will disclose differences in transmission in every stratum and in the same stratum at different points and at different times. Such a situation is inseparable from the conditions of distribution of seston in the water. But in general these differences are such that an average transmission can be assigned to the region in question. The situation is easily seen from the diagrams in which the observed percentages are platted as well as those computed for zenith sun.

This construction of the diagrams enables them to show the kind of approximate accuracy which can be assigned to this average transmission. It would require a very steady sun and an unusually uniform lake to make the assigned mean quite certain. Ordinarily the sun is not quite steady and the distribution of suspended material in the lake is never perfectly uniform over such small distances as one meter. Thus the situation is very commonly such that it would be quite possible to place the mean value a point higher or lower than that

chosen. Similar variations are also to be expected in the average transmission found in series from the same lake taken at short intervals, during which no observable change has occurred in the plankton. If longer intervals elapse much more considerable changes may be found, as is shown by the record of Lake Mendota (Birge and Juday, '29, p. 543). On the other hand, a lake ordinarily preserves its general character from week to week and from year to year, as the tables of our papers abundantly show.

In certain cases very considerable variations are observed in individual strata. The most conspicuous example in the present series is offered by Crystal Lake (fig. 2) between 8 m. and 10 m. Here for a distance of two meters the transmission exceeded 90 and then fell off, so that the average transmission from 8 m. to 13 m. was the same as from 1 m. to 8 m. This increase between 8 m. and 10 m. was not due to a momentary increase of radiation, since the sun was steady in a cloudless sky. It was not an accident of observation, since it was found in the transmission of the several colors as well as in that of the total radiation. It is to be compared with those holes in a fog on land which are often seen for a few minutes. It was a temporary matter in this case, since it was not present in a

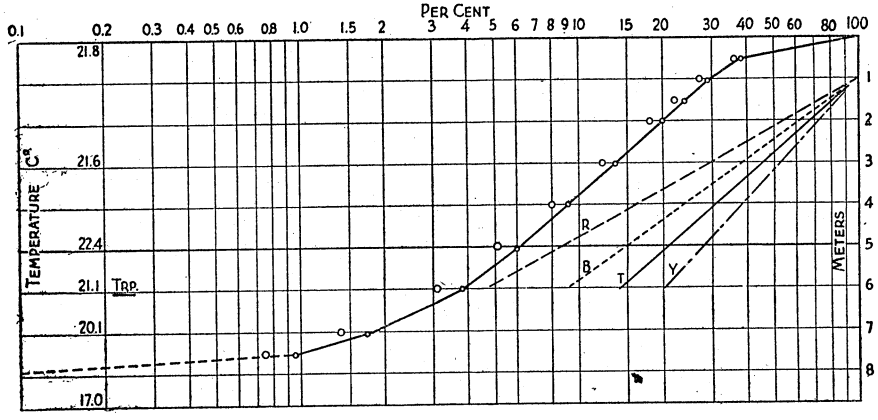

FIG. 5. Finley Lake, July 19, 1929. The temperatures are of Aug. 10. Transmission of radiation was probably unusually great on July 19, since on no other date has a transparency been found greater than 4.5 m. There was a large accumulation of seston in the bottom water. The millivoltmeter read 28 divisions at 7 m., 14 at 7.5 m., and there was a barely perceptible movement at 8 m., which depth was practically the bottom.

second series of readings, extending to 10 m. and made about one hour later. A similar transparent stratum was present in Day Lake (fig. 3), and other cases have been recorded.

The intermediate region in the six lakes under discussion offers interesting differences, as may be seen from the diagram. Hillis Lake (fig. 6) hardly shows an intermediate region. In the lower part of the epilimnion the increase of suspended material reduces the transmission and the decrease is even more conspicuous in the thermocline. In Finley Lake transmission is almost exactly uniform from 1 m. to the bottom of the epilimnion and the intermediate region ends at that level. In Day Lake (fig. 3) and Weber Lake (fig. 7) transmission is uniform from 1 m. through the epilimnion and into the thermal regions below it. There is no accumulation of suspended material in the upper levels of the cold water, nor is there any growth of plankton in the thermocline. In Crystal Lake (fig. 2) a similar condition extends for at least four meters of the thermocline and hypolimnion, while in Diamond Lake (fig. 4) transmission begins to decrease after one meter of the thermocline has been passed. This is correlated with the small thickness and volume of the colder water in Diamond Lake.

The lower part of the transmission curves also shows interesting differences. In the small and shallow Hillis Lake the decrease in transmission begins even before the colder water is reached and radiation disappears rapidly in the bottom water. This situation is due in part to increased color in the lower water (table 1); in part to suspended material in the form of debris; and also to a large growth of Peridinium in the lower water at the time of observation. There was no growth of plankton in the lower water of Finley Lake, but the deeper water of this lake occupies only a small area. In such cases currents of water collect much debris from the bottom in shallower water and sweep it into the deeper strata. Day Lake shows a typical case of transmission continuing unchanged into the deeper water and then falling off very rapidly as the bottom is approached. In this case both suspended material and color play a part (table 1). Weber Lake offers an extreme case of a different kind. Here the transmission continued almost unchanged to the bottom. The deepest reading was made less than a decimeter above the bottom, which is covered by a growth of the moss Drepanocladus. In Diamond Lake the

thickness of the colder water is less than in Day Lake and its volume is much smaller; as a consequence the suspended material is denser and offers increased obstruction to radiation throughout almost the whole extent of the hypolimnion. Finally, Crystal Lake carries its intermediate region well down toward the bottom and shows only a small decrease in transmission as the bottom water is reached. In this lake the bottom water showed only a trace of color and the last reading was made about one meter above the mud.

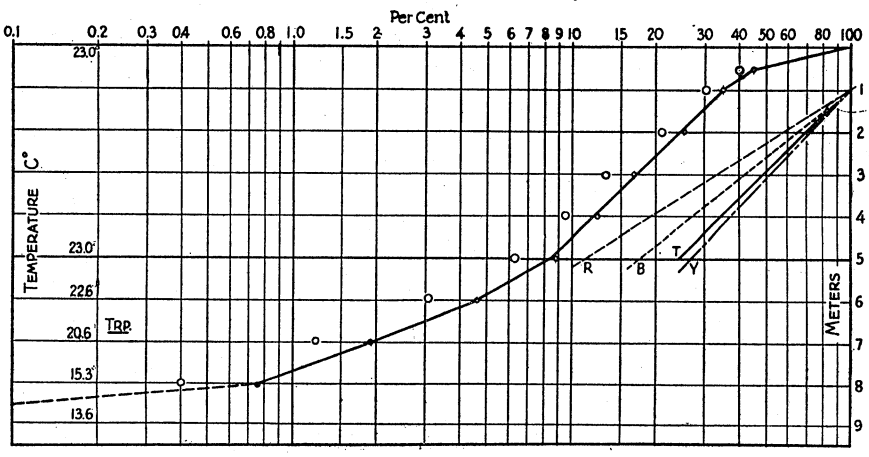

FIG. 6. Hillis Lake, July 16, 1929. Temperatures of July 20. The hypolimnion in this lake is always stained, colors of 35 to 100 being recorded for the bottom water. The scale reading of the millivoltmeter at 8 m. was 5.5; no visible response at 9 m.; total depth slightly over 9 m. Note uniform transmission between 1 m. and 5 m. and decrease from that depth, which is still in the epilmnion. There was a large growth of Peridinium in the hypolimnion, besides much seston.

The records from these six lakes, together with the observations of Oberdorfer on the Bodensee, show that this general form of the curve is characteristic for lakes whose transmission is "high" or near that level. There can be no doubt regarding the form of the curve in the surface meter or of that in the bottom water. A question may be raised regarding what we have called the middle region. Is the average transmission there *uniform,* in the sense in which we have used the word, or does it vary so much at different depths that we ought not to make any general statement? Our readings belong to a season of the year when irregularity should be at a maximum,

and are therefore as convincing as any such number can be. Oberdorfer's observations show a considerable vertical change in transmission at certain seasons of the year, but an average which comes well within our term *uniform*. He is ready to assign "average transmission" in all cases from 0 m. to 20 m.

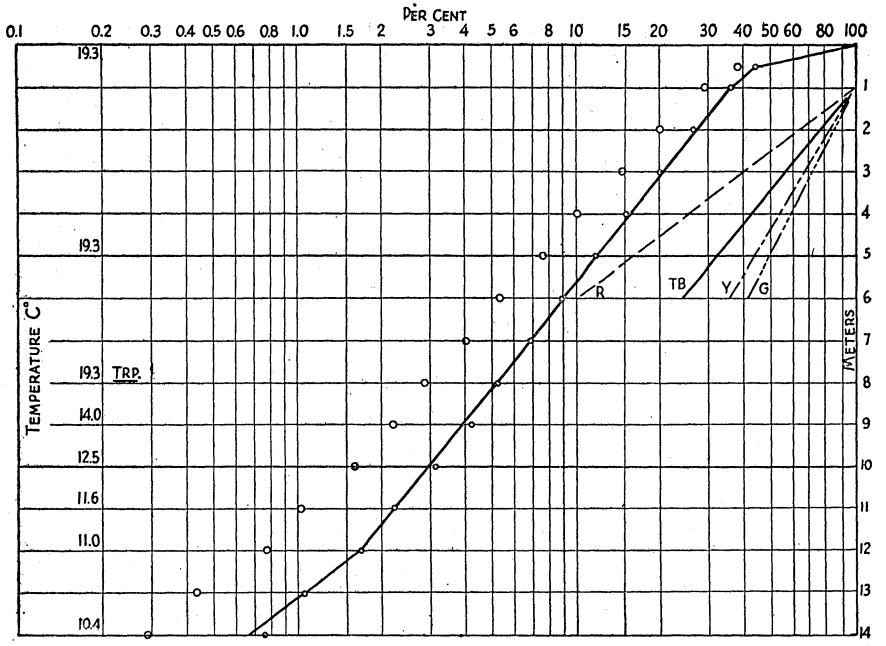

FIG. 7. Weber Lake, Aug. 23, 1929. This lake shows a singularly uniform transmission with very slight decrease as the bottom is approached. This continued transparency may possibly be connected with the active growth of Drepanocladus on the bottom, with consequent inability of currents to move particles of mud. The quantity of centrifuge plankton is always considerable for such a lake. On Aug. 21 there were 1.13 p.p.m. at surface, 0.98 p.p.m. at 8 m., and 0.84 p.p.m. at 13 m. Ordinarily the plankton catches at bottom and surface of the lake are about equal. The color is usually recorded as zero at all depths, or with very low reading at bottom. Transmission usually about 75, decidedly lower than that of the neighboring Crystal Lake; it is probably affected by the relatively large amount of seston.

His readings went to a maximum depth of 30 m., and his results are of the kind that we should expect to find in any one of our lakes, if we should follow it through the year.

Transmission in lakes of other types, so far as it is influenced by color, should show the same characteristics; since we find

that color is ordinarily distributed with much uniformity until the water near the bottom is reached. Lakes with low color and much plankton are undoubtedly more variable in the rate of transmission through strata at different depths. Seston may cause a marked decrease of transmission in certain strata, as it did in Marl Lake (Birge and Juday, '29, p. 559) between 8 and 10 m. An equally marked rise is just as possible, though as yet we have not found such a case. But we should expect the average transmission for a year or a season to work out with a fair degree of uniformity in the middle region; such uniformity that we can assign a characteristic transmission to this region of the lake.

In deep lakes, such as Green and Trout lakes, we should expect the middle of the hypolimnion to show higher transmissions during summer than strata above or below, because the centrifuge shows that there is less plankton in this region of the lake. The weight of centrifuge plankton from these depths may be only one-half, or even a smaller fraction of that found at surface or bottom. The transmission of light in this region has never been explored in any lake of this type.

2. OBSERVATIONS OF 1929 COMPARED WITH THOSE OF EARLIER YEARS

In the case of 17 lakes comparison may be made between the transmission of radiation observed in 1929 and that found in earlier years. The earlier observations are reported in Birge and Juday, '29, pp. 559–563. In that paper no attempt was made to follow radiation to a smaller value than one per cent of that incident on the surface of the lake.

Most of the observations of 1929 were made in connection with studies of color transmission and the total radiation was not always followed to the greatest possible depth. This was the case in Clear, Kawaguesaga, Lost Canoe, Pauto, and White Sand lakes. The observations in Weber Lake extended to the bottom; those in Crystal Lake ended about one meter above the bottom; both went into that region where transmission is diminished by accumulated suspended material. These two lakes are discussed in section 1 of this paper. In most of the other lakes the value of the lowest reading is small and the transmission curve below the depth of one meter is practically

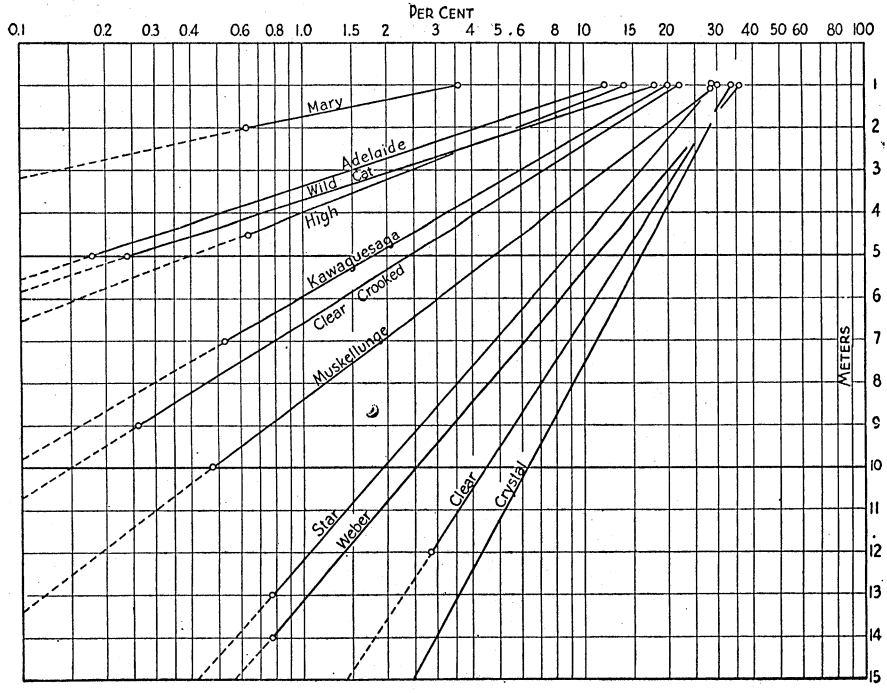

FIG. 8. Transmission curves for lakes observed both in earlier years and in 1929. The diagram is to be compared with figs. 3, 4, and 5 in our earlier paper (Birge and Juday, '29). Two of the curves in the diagram, those from Crystal and Weber lakes, are given in full in figs. 2 and 7. The present diagram includes three logarithmic cycles, extending to 0.1 per cent.

The lakes represent all of the main classes. 1. Lakes whose transmission in the first meter is over 30 and is over 70 below this depth—Clear, Crystal, and Weber lakes. Star Lake, whose transmission in the first meter is less than 30 and is 74 below, really belongs to the same class. 2. Lakes with high medium transmission—Clear Crooked, Kawaguesaga, and Muskellunge lakes. In these lakes the transmission in the first meter lies between 20 and 30 and is between 50 and 60 below. 3. Lakes with low medium transmission—Adelaide, High, and Wild Cat lakes. These lakes have a transmission between 10 and 20 in the first meter, and less than 40 below. 4. Lake Mary is an extreme example of the lakes with low transmission, since it retains at the depth of one meter only 3.6 per cent of the radiation incident on the surface and its transmission below that depth is only 16.

a straight line when platted on semi-logarithmic paper. There need be no hesitation in extending it over the short distance needed to reach the value of 0.1 per cent of the radiation incident upon the surface of the lake, i. e., to one-tenth of the value shown in our earlier paper. The additional depth needed to reach this value is often less than one meter, rarely more than two.

The most transparent lakes offer exceptions to this statement. In Clear Lake one per cent of incident radiation would be found at the depth of about 16.4 m.; and at the average rate of transmission about 10 m. more would be required to reduce the value to 0.1 per cent. This depth is so near the bottom of the lake that we cannot assume that the transmission found above 12 m. extends so far, and probably the value of 0.1 per cent would be found above 26 m. In the case of Pauto Lake one per cent of incident radiation would be found at about 14 m. if the average transmission extends to that depth; but in this lake, which is 17 m. deep, much suspended material is found by the centrifuge in the hypolimnion and any considerable extension of transmission curves is subject to much doubt.

In general, the observations made in 1929 and those from earlier years have the kind of agreement that would be expected. They show that we were warranted in extending the transmission curves in the diagrams of the paper of 1929 to the value of one per cent of the incident radiation. They show also that in many cases the transmission curve continues, practically unchanged, until the value of 0.1 per cent is reached. The last statement holds only for lakes whose depth is such that the value in question is reached before the bottom water is approached and before the transmission is correspondingly reduced. It must also be modified for lakes whose hypolimnion has a small thickness and volume, especially if growths of plankton are possible in that region. Two cases of this sort are discussed in the earlier part of this paper.

TABLE 3. *Lakes observed in 1929 and in earlier years*

NOTES

1 Lake	2 % at 1 m.	3 Trans.	4 1% at m.	5 % at m.	6 Trans. m.	7 Dist. m.	8 Depth	9 % at Max. Depth	10 1% at m.
Adelaide	12	34	3.5	12	35	1–5	5	0.14	6.2
Clear	32	74	12.5	34	80	1–10	12	1.68	16.4
Clear Crooked	31	58	7.5	22	57	1–9	9	0.12	6.6
Crystal	38	81	17.1	34	83	1–15	19	0.41	18.0
Fishtrap	16	45	4.6	14	37	1–6	6	0.17	4.5
High	15	36	3.6	14	38	1–5	4.5	0.21	3.8
Kawaguesaga	18	40	4.2	21	55	1–7	7	0.38	6.0
Lost Canoe	21	62	7.4	30	59	1–7	8	0.30	6.8
Mary	4.7	24	2.0	3.6	16	1–2	2	0.30	1.7
Muskellunge	27	70	8.2	30	60	1–9	10	0.13	8.4
Pauto	34	70	10.9	35	77	1–10	10	2.16	14.5
Plum	24	62	7.7	21	59	1–5	5	0.30	6.4
Star	26	65	8.2	29	74	1–10	12	0.30	12.0
Trout	27	67	8.1	24	63	1–12	12	0.08	8.0
Weber	34	79	16.3	36	75	1–10	14	0.29	13.1
White Sand	19	53	5.4	26	56	1–6	7	0.70	5.6
Wild Cat	16	37	3.7	16	34	1–5	5	0.25	4.2

Cols. 2–4. Earlier observations.
Cols. 5–10. Observations of 1929.
Col. 2. Crystal and Trout lakes have mean of all earlier observations.
Cols. 3 and 6. Mean transmission, zenith sun.
Col. 7. Distance in meters over which mean transmission is measured.
Col. 8. Depth of lowest observation.
Col. 9. Per cent of incident radiation found at greatest depth. Not adjusted for zenith sun and hence differs from results in col. 10.
Cols. 4 and 10. Depth at which one per cent of incident radiation would be found with zenith sun.

This paper and its predecessor furnish a general idea of the transmission of solar radiation in 72 lakes, 68 of which are in Wisconsin. This number is by no means great enough to warrant the assertion of definitive conclusions, but it is so much larger than the number already on record that a tentative classification of lakes may be indicated.

TABLE 4—*Classification of Wisconsin lakes according to transmission*

Transmission	*Southeastern*		*Northeastern*		*Total*	
	Number	*Per Cent*	*Number*	*Per Cent*	*Number*	*Per Cent*
Low, 0–30	1	4	7	9	8	12
Low medium, 31–50	4	15	10	24	14	20
High medium, 51–70	18	67	16	39	34	50
High, 71 and over	4	15	8	20	12	18
	27	100	41	100	68	100

Of the four lakes outside of Wisconsin (Birge and Juday, '29, p. 563) three are in New York and one in Iowa. Three belong in the high medium class and one (Seneca) just enters the high class.

The main interest of this table lies in the striking difference between the transmission of the lakes in the two districts. Southeastern Wisconsin has many lakes with high medium transmission and very few below that grade. In this respect it contrasts sharply with the northern district. This difference depends chiefly on the presence in the Highland Lake District of numerous lakes with deeply stained water, a type which is nearly or quite absent from the southern part of the state. A much larger series of lakes from both districts would probably show much the same difference. No color higher than 35 on the platinum-cobalt scale has ever been observed in southern lakes, and this only once. In these lakes suspended material is the main factor limiting transmission, and lakes like Mendota, which often have a low medium transmission, have also a great range of transmission according as plankton is present in large or small quantity.

In the northeastern lakes stained waters are far more common. The color of 477 lakes in this region has been determined and 125, or practically one-quarter, have a color of 60 or above; while 67 or 14 per cent have more than 100. None of these is likely to have a transmission which exceeds 30, even when suspended material is scanty. About 12 per cent are recorded as having no color as measured by this scale, and 11 per cent more have colors below 10. Thus another quarter of the lakes would often have a transmission in the upper part of *high medium* or in the grade of *high,* the position depending primarily on the amount of seston. These soft water lakes have a less abundant plankton than is present in the hard water lakes of the south.

Thus we have reason to believe that the lakes whose transmission is recorded give a fair picture of average conditions in their respective districts.

3. TRANSMISSION OF RADIATION PASSED THROUGH LIGHT FILTERS

This section of the present paper reports on the transmission of visible solar radiation through the water of lakes. It deals with the transmission of total visible radiation and also with radiation which has passed through filters representing different parts of the spectrum. In all cases three regions of the spectrum are considered—blue, yellow, and red. The transmission of radiation belonging to these regions is determined and is compared with that of the entire visible spectrum, as this is represented in the several lakes. For about one-half of the lakes the transmission of radiation belonging to the region of the green is similarly studied.

The transmission in lakes of radiation of different wavelengths differs greatly, since parts of the visible spectrum are transmitted variously by pure water and are also very differently affected by stains dissolved in the water and by seston. It is possible to infer from the transmission something as to the changes in composition which the light experiences in passing through the water. But in this paper no attempt is made to determine the quantity of radiation from each several region, either in the total energy spectrum or in that present at different depths in the lakes. This matter is left for future discussion.

METHODS

The light filters

The light filters regularly used in 1929 were Wratten filters, supplied by the Eastman Kodak Company, of Rochester, N. Y. Each consists of a film of colored gelatine cemented between two pieces of optical glass. The filters are 58 mm. in diameter and are provided with a metal rim.

Four filters were used, three of which were regularly mounted in the pyrlimnometer and were used on all occasions and at all depths. The instrument was not constructed to carry a larger number, and therefore the fourth or green filter had to be read in a separate series. The following table gives the most important facts regarding the relation of these filters to the spectrum.

TABLE 5—*Wratten light filters*

Number	*Color*	*Limits of transmission*	*Center of transmission*
47	Blue	3900–4200 Å	4500 Å
58	Green	4800–6100	5200
16	Yellow	5250–on	
26	Red	5900–on	
16—26	Yellow	5250–5900	5700

The colors of the spectrum may be variously limited. The following data come from Landolt and Börnstein, Physical Tables, 1923, p. 806.

TABLE 6—*Limits of colors, wave-lengths*[1]

Color	*Wave-Lengths*[1]
Violet	3600–4240 Å
Blue	4240–4920
Green	4920–5350
Yellow	5350–5860
Orange	5860–6470
Red	6470–8100

Thus the range of filter 47 covers the region of blue and filter 58 covers the green in a similar way. The upper limit of filter 16 overlaps the green region a little and extends to the end of the visible spectrum; filter 26 covers both the orange and the red, including practically the spectrum from about 6000 Å on.

The transmission of these filters in the spectrum between 4000 Å and 7000 Å is given in the catalogue of Wratten Light Filters issued by the Eastman Kodak Company, pp. 63–75, and need not be repeated here. The transmission of radiation of greater wave-length than 7000 Å is not given in the catalogue and is of much significance in the work on lakes. The Eastman Company kindly determined the transmission of our filters in the region 7000 Å–8000 Å.

All light-filters of glass or gelatine transmit infra-red radiation. It is therefore not practicable to establish the base for comparing the transmission in water by readings in air or immediately below the surface of the lake. Such readings will

[1] In our work we have regarded the visible red as ending at 7621 Å or the A line.

include the effect of an unknown quantity of infra-red radiation in addition to that belonging to the spectral region whose name the filter bears. The transmission of infra-red radiation in water is very small; all of that in the solar spectrum is practically eliminated by one meter of water and readings taken at this distance below the surface of the lake represent the effect of the visible spectrum. Thus the readings of filters 47 and 58 at the depth of one meter and below represent radiation belonging respectively to the regions of blue and green; those of filter 16 represent the lower part of the spectrum from 5250 Å to about 7660 Å; those of filter 26 extend from 5900 Å to the same lower limit; the difference between the readings of filters 16 and 26 shows the effect of radiation between 5250 Å and 5900 Å.

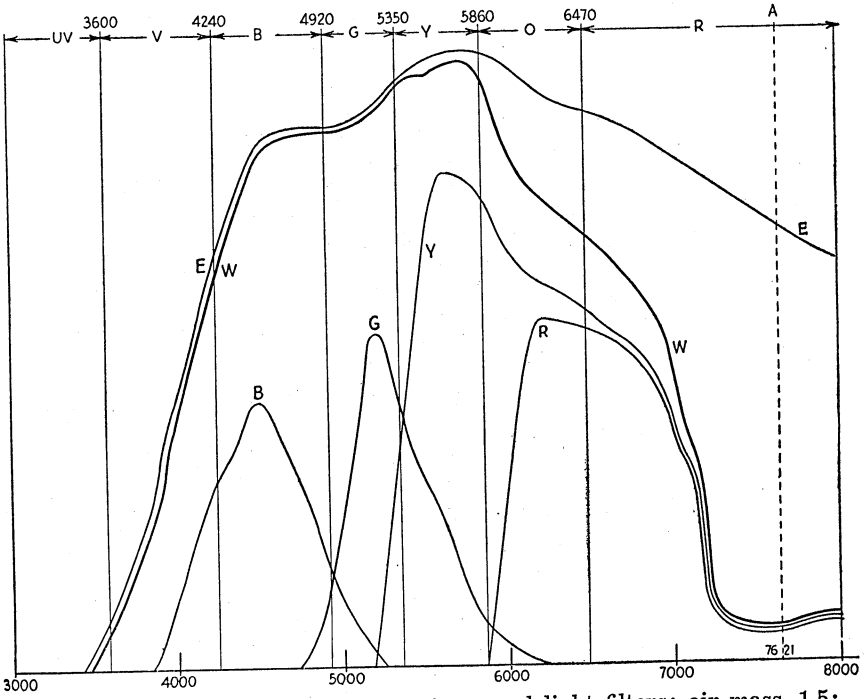

FIG. 9. Normal solar energy spectrum and light filters; air mass, 1.5; precipitable atmospheric water, 2.4 cm. E–E, envelope, or energy spectrum in air; W–W, spectrum at depth of 1 m. in pure water; B, curve for Wratten filter No. 47; G, filter No. 58; Y, filter No. 16; R, filter No. 26. See p. 308. The ordinates for the envelope were kindly furnished to us in 1916 by Mr. F. E. Fowle of the Smithsonian Institution.

Light Filters and the Energy Spectrum

The quantity of radiation transmitted by the several filters interests us at present chiefly as determining the depth to which observations on the spectral regions can be carried, as compared with the depth to which observations on the total radiation can be made. Any filter transmits only a part of the total energy of the spectrum and only a part of that in the spectral region which it represents. The fraction of the total will depend in part on the capacity of the filter and in part on the per cent of total radiation which is contained in the region represented by the filter. The first factor is a constant; the second depends on the form of the energy spectrum, which, when measured in air, varies with the air-mass through which the radiation has passed, with the transmission coefficient of the air, and with the amount of water vapor, dust, etc., present in it. For our present purposes it is enough to assume an energy spectrum fairly similar to one that may frequently be present in practice and to determine the quantity of energy from this spectrum which is transmitted by each of the filters.

Figure 9 shows a normal energy curve of the solar spectrum constructed for air-mass 1.5, corresponding to a solar elevation of 41.7°; the presence in the air of 2.4 cm. of precipitable water is assumed; the effect on this spectrum of its passage through one meter of pure water is determined, using for this purpose the absorption coefficients of Aschkinass ('95). On this energy curve, thus determined for the depth of one meter, are platted the transmission curves of the several filters, using the data given in the Wratten catalogue, pp. 64–70. The area enclosed by the energy curve is measured and also the areas enclosed by the curves of the several filters. The result is as follows:—

Table 7—*Per cent of total energy transmitted by various filters from spectrum described above*

Filter No.	*Color*	*Per cent*	*Remarks*
47	Blue	11.6	
58	Green	12.1	
16	Yellow	44.8	measured to A line
26	Red	23.7	measured to A line
16—26	Yellow	21.1	

Percentage of Energy Spectrum Transmitted in Lakes by Filters

This percentage transmitted by the filters under these assumed conditions may be compared with that actually found in lakes. As a general statement it may be said that filter 47 (blue) at the depth of one meter in fairly transparent lakes gave a swing of the millivoltmeter from 10 per cent to 15 per cent of that caused by the total radiation at the same depth; filter 58 (green) under similar conditions transmitted 13 to 18 per cent; filter 16 (yellow) from 40 to 60 per cent; and filter 26 (red) gave from 25 to 40 per cent of the total radiation. In extremely high colored lakes the swing of blue at one meter might be too small to measure, as is shown by table 8, or it might be a very small per cent of the total. In such cases almost all radiation at one meter comes from the longer waves of the spectrum and filter 16 may transmit more than 80 per cent of the total and in extreme cases filter 26 may rise to 85 or even 90 per cent.

From this statement it follows that the maximum swing of blue under the conditions stated is from 60 to 80 divisions of the scale of the most sensitive millivoltmeter, while that of total radiation computed on the same scale, would be 400–500 divisions. The blue radiation can not be followed to so great a depth as the total, especially as in many lakes blue has the smallest per cent of transmission from meter to meter. Thus in Crystal Lake total transmission was followed to 19 m. and could have been followed to greater depths, while blue became too small to read at depths below 15 m. Filter 16 permitted reading to much greater depths than did either 47 or 58. In general, blue "ran out" first; then green; then red; then yellow. In figures 12–15 the depth is indicated to which the several colors were read.

Changes in Energy Spectrum in Passing Through Lake Water

Figure 9 enables us to understand the general course of transmission in an ideal lake containing pure water without plankton. The area of the envelope E–E, measured to the A line, divides at 5600 Å into two nearly equal parts. The trans-

mission of the part toward the blue, including violet, blue, green and a little of yellow, is very high and nearly uniform. Transmission toward the longer wave lengths declines rapidly, falling off from 98 at about 5700 Å to less than 9 at 7500 Å.

Thus as light passes downward through such water the radiation that has a wave length greater than 5700 Å is rapidly absorbed and disappears from the energy spectrum. That from the other half of the spectrum is absorbed very slowly and not very unequally. Blue, green, and yellow, in such depths as are found in inland lakes, maintain about that amount of energy relatively to each other, which they have in the incident radiation; the percentage which each contributes to the total found at any depth, rises as the base becomes smaller by the elimination of red, and later of orange radiation.

The general effect of suspended matter and of stain in the water can also be inferred from the diagram. Harvey ('28, p. 158) has pointed out that the observations of Pietenpol ('18, p. 575) show that the transmission of short wave radiation is more affected by seston than is that from longer wave lengths. The extractive material found in our lakes has a color of yellow or brown. Thus both color and seston offer more obstruction to the short waves than to the long ones. Their effect is to make the blue end of such a diagram as fig. 9 approach the form of the red end—having a smaller transmission in blue than in green. In the most transparent lakes, therefore, as they actually exist, blue, green, and yellow should have about the same transmission, with blue the smallest, though all of them are high. As transparency diminishes, blue should fall off most rapidly; green, and then yellow, more slowly. Yellow should come to have the maximum transmission, except in the most deeply stained waters, in which yellow may be reduced below orange or even red. The later account of observations will show how nearly these expectations are fulfilled in fact.

Observations

Each series of readings began with a determination of total radiation in the air; the same reading closed the series unless it was broken off by cloud. The first reading in the water was at the depth of 50 cm. and was followed by readings at 10 cm. and 25 cm. if the surface of the lake was sufficiently smooth.

Readings were made at one meter and at each meter below; in opaque lakes readings were also taken at 1.5 m. and 2.5 m. In very transparent lakes some of the single meters might be omitted below 10 m.

A set of readings at any depth involved six readings of the pyrlimnometer taken in the following order: zero, blue, red, yellow, open, zero. The order was arranged so that in ordinary lakes the swing of the millivoltmeter might increase throughout the series. The shutter of the instrument had only five openings so that the transmission of the green filter had to be read in a separate series.

Under favorable conditions readings could be made rapidly. In Crystal Lake 10 such sets, involving 60 readings, between the depths of 10 cm. and 5 m. were made in 18 minutes; in Little Tomahawk Lake 6 sets or 36 readings were made in 13 minutes. In general about two minutes intervened between the beginning of one set and that of the next, which would be one meter below the first. If cumulus clouds were present so that clear spaces of sky must be waited for, work was correspondingly delayed. When the epilimnion had been passed and observations were made in the colder water below, it was necessary to wait until the pyrlimnometer had assumed the temperature of the water. Under such conditions from 4 to 6 or 7 minutes were needed for each set. A complete series on Crystal Lake, extending to 19 m. and including 189 readings of the pyrlimnometer, required 83 minutes, from 11:15 a. m. to 12:38. This was unusually rapid work; a similar series on Clear Lake, extending to 12 m. and 171 readings, required 134 minutes.

Data

The first series of observations was made on June 28, the last on August 29. During the interval 46 series were made on 35 different lakes. They extended to depths ranging from 2 m. in the most opaque lakes to 19 m. in the most transparent, as is shown in table 8. No attempt was made to go below 10 m. until after August 1. The readings of the pyrlimnometer in these series aggregated 4435; in addition 716 readings were made in the course of experiments, such as testing different types of filters.

Object and Limitations of Study

The object of the study was to ascertain the transmission of the several kinds of radiation, not the quantity which each contributes to the total radiation present at any given depth. The average transmission was the subject of investigation, rather than the variations in transmission, due to density of seston in the water and similar accidental circumstances. In interpreting the readings of color transmission the base for comparison is the reading obtained at one meter below the surface of the lake. This is taken rather than a reading in the air or at a higher level in the water, in order to eliminate the effect of the infra-red radiation. The transmission of the uncolored radiation—the "total"—which is compared with that of the several colors, is also based on the reading at one meter. Thus all radiation treated in this part of the report has passed through what may be regarded as a sort of light-filter consisting of one meter of water from the lake under observation. The Wratten filters for the several colors are read as they affect radiation after it has passed through the first meter of water. This stratum removes not only the infra-red radiation but also part of that in the visible spectrum (see fig. 9). The question then arises: is the transmission of the total visible spectrum in the upper meter, and that of the several colors, like that which is found below, so that the transmission curves ascertained for the deeper water may be extended up to the surface? Or is the transmission in the upper meter decidedly smaller than that immediately below?

The answer differs for the different colors, primarily according to the transmission through pure water of the spectral band in question. If transmission is approximately uniform through the whole breadth of the band represented in a filter, the transmission in the upper meter will be the same as that below, barring accidental obstruction from plankton, etc. This is the case for the blue filter, the green, and in general for the yellow band represented by the difference between filters 16 and 26.

If there is a wide difference in the transmission of the different wave lengths represented in the spectral band, the transmission in the upper meter must be less than that below. This

statement holds for the red filter and also for the total radiation. The situation can be seen from fig. 9.

If stains or other obstructions to radiation are present in the water and are such as to create a differential transmission for the parts of any spectral band, the above statements must be modified in accordance with the facts. For general purposes no serious error will be made if the transmission curves are thought of as extending up through the first meter with the same rate that they have in the second meter: but details will not be accurately rendered.

TABLE 8. *Transmission of colors, 1929*

1	2	3	4	5	6	7	8 TRANSMISSION	9	10	11
Lake	Date	D'pth obser. m.	Trp. m.	Color	Cos r	Total	Blue	Green	Yellow	Red
Adelaide	Aug. 29	5	2.7	35	0.88	35	12	32	40	35
Big Carr	July 13	8	7.6	0	.94	65	59	------	76	57
Bragonier	July 19	4	2.9	45	.92	26	8.5	------	25	25
Clear	July 30	12	9.2	0	.86	80	77	82	84	60
Clear Crooked	Aug. 19	9	4.3	16	.84	57	45	62	67	52
Crystal	Aug. 7	15	11.2	0	.90	81	81	85	84	68
Crystal	Aug. 23	19	12.2	0	.90	83	82	86	84	67
Day	July 29	12	7.6	0	.87	74	74	------	79	59
Diamond	July 25	11	10.8	0	.85	85	82	------	80	68
Finley	July 19	8	6.2	0	.94	69	62	------	73	55
Fishtrap	Aug. 18	6	2.6	22	.90	37	15	31	42	34
Helen	July 2	3	1.7	88	.95	24	2	------	10	23
High	Aug. 8	5	3.5	10	.85	41	29	45	47	36
Hillis	July 16	9	6.9	4	.88	70	65	------	71	58
Johnson	July 30	7	3.7	18	.90	58	42	60	66	47
Kawaguesaga	July 18	7	3.5	8	.94	55	45	------	66	51
Little Bass	July 8	10	7.0	0	.90	75	69	------	80	60
Little Pickerel	July 19	2	1.4	132	.85	8	?	------	?	8
Little St. Germaine	July 19	6	2.8	22	.93	42	22	------	40	42
Little Tomahawk	July 13	10	6.9	4	.94	75	70	------	78	67
Long	Aug. 17	6	5.0	18	.89	46	29	51	51	40
Lost Canoe	July 4	8	4.4	11	.95	59	47	------	71	55
Mary	Aug. 29	2	2.1	118	.85	16	0.4	9	10	18
Midge	Aug. 15	3.5	2.9	58	.87	24	2	------	22	28
Muskellunge	July 18	10	4.4	6	.88	60	55	64	68	52
Papoose	Aug. 15	9	5.3	20	.85	58	41	64	64	51
Pauto	July 15	10	8.3	0	.90	77	73	------	82	62
Plum	July 19	6	4.7	16	.81	59	47	------	60	56
Silver	July 26	10	6.5	0	.92	69	67	------	76	60
Star	Aug. 26	13	8.1	0	.86	74	67	74	79	61
Trout	Aug. 6	12	5.0	6	.92	59	53	68	68	55
Turtle	July 5	4	1.9	69	.85	23	1.5	------	23	19
Weber	Aug. 23	14	6.9	0	.83	75	75	84	81	63
White Sand	July 4	7	3.9	16	.85	56	40	------	63	54
Wild Cat	July 29	5	2.5	26	.83	34	17	------	39	34

NOTES ON TABLE 8

Col. 3 states the depth to which total radiation was followed. The limit was set by various circumstances in different lakes. See p. 311.

Col. 4, transparency, states the depth at which Secchi's disc disappeared. Diameter of disc, 20 cm.

Col. 5. Color is measured by the U. S. Geological Survey or platinum-cobalt scale. This has the advantage of giving a numerical value to each shade within its range and the color can be accurately reproduced if desired. It has the disadvantage of applying only to waters stained with yellow and brown colors. Clear waters with a slight tinge of green—like Crystal and Diamond lakes—show no color on this scale. Ratings below 8 are estimates based on comparison with the lowest standard color disc which is 8.

Col. 6 states the cosine of the angle of refraction of the direct rays of the sun, corresponding to its mean altitude during the observations.

Cols. 7–11. The accuracy of these figures in the most opaque lakes is less than in those given for the more transparent waters. In general, transmissions less than 8 are based on readings separated by smaller distances than one meter, and in the case of blue, they may come from readings in the upper meter. The accuracy of such figures is correspondingly uncertain.

In cases where lakes are so opaque that radiation can be followed for two or three meters only, there is uncertainty as to the situation in the lower water. Transmission is surely still very low but it may well be higher than the figure assigned to the upper water.

Cols. 8–10. In these columns the question mark (?) means that transmission was zero or too small to measure.

Col. 9. In this column the sign ____ means no observation.

Col. 10. The transmission of yellow is computed from the readings of filters 16 and 26. The reading of 26—the red filter—at the several depths is subtracted from that of 16—the yellow filter—and transmission is computed from the results thus obtained.

Average Transmission

The transmission of the several colors is uniform from meter to meter in the same sense as that in which the word is applied to the transmission of the total radiation (p. 300). It is subject to many accidental variations, but these are usually small and an average number can be assigned to transmission of each color in the same way and with the same limitation of accuracy as it can be assigned to total radiation. This is done in table 8; and in the following diagrams the average transmission is platted for the several colors, without attempting to show the variations from meter to meter. In both table and diagrams the observed percentages are adjusted for zenith sun as stated for total radiation on p. 288.

Results

The general result of the study is shown in table 8, on which the following discussion is based. Inspection of the table

shows that radiation was followed to very different depths in the various lakes. In the most deeply stained waters, such as those of Mary, Helen, and Turtle lakes depths of only two or three meters were reached. In such cases the accuracy of the assigned transmissions is less than in more transparent lakes where radiation could be observed to greater depths.

There is a general relation between the values of transmission of total radiation and that of the several colors, such that high or low values of one accompany similar values of the others. But there is no exact correspondence, rather a marked variation, in such relations. For instance, the transmission of total radiation in Muskellunge Lake is 60 and in Papoose Lake it is 58; that of blue in the same lakes is 55 and 41 respectively. Transmission of yellow in Helen Lake is 10 and in Midge Lake 22, although the transmission of total is 24 in both lakes.

Behavior of the Several Filters

Filter 47—Blue

The center of transmission for the blue filter lies about 4500 Å, and therefore near the center of the blue region of the spectrum. The transmission in water of radiation which has passed through it has a smaller average value than that of any other filter and it has the greatest range of variation. In the most highly colored waters, such as those of Little Pickerel, Mary, Midge, Helen, and Turtle lakes, very little radiation from this region remained at one meter's depth and at two meters there was not enough to give more than a slight indication of an effect. Under such conditions the transmission was doubtfully computed from readings between one-half meter and one meter. Little value should be attached to the exact figures given; in such waters the determination of transmission of blue is a matter for the laboratory rather than the field. Practically, one meter of such water cuts off the blue.

Pure water transmits radiation of the wave lengths passed by the blue filter at rates close to the maximum. The situation disclosed in lakes by the observations means that short wave radiation is more affected by stains dissolved in the water and also by suspended matter than is radiation of greater wave length.

Filter 58—Green

Filter 58 was read in only 15 lakes, and the observations are correspondingly few. They include lakes with high and with low transmission and probably show the range of this radiation. The center of the spectral band covered by the filter lies near 5200 Å and therefore about half way between the centers of the bands assigned to the blue and the yellow radiation. The transmission of the radiation passed by this filter is what would be expected from its position in the spectrum; it is ordinarily higher than that of the blue and lower than that of the yellow. Where the blue radiation has a transmission about equal to that of the total, that of the green is somewhat higher. In lakes which have a bluish green color the highest transmission should come in the region of green. This seems to have been the case (table 8) in Crystal and Weber lakes; but the number of observations is so small that it is not safe to generalize from them.

Filter 16—Yellow

The range of filter 16 is from 5200 Å to the end of the visible spectrum, and it therefore includes the regions of both yellow and red.

This filter was used in all observations, but little direct use has been made of its readings and they are not included in the table. They have been employed to determine the transmission of radiation from a spectral region between wave lengths 5200 Å and 5850 Å, by subtracting the reading given by filter 26 at the successive depths from that of filter 16. The result is to give the reading of a spectral region whose center is near 5700 Å.

The upper limit of filter 16 lies at a point in the spectrum where pure water transmits 98 per cent or more of incident radiation and at the lower limit—say, at 7621 Å—the transmission is less than 9. In general the radiation derived from this filter shows a higher transmission than that from filters nearer the ends of the spectrum, such as filters 47 and 26. This is true in spite of the fact that red is included within its transmission.

In several of the lakes with the highest color, including Adelaide, Bragonier, Little St. Germaine, and others, the transmission of radiation from filter 16 was no larger than that of filter

26. This situation means that in such lakes most of the radiation present at and below one meter comes from the part of the spectrum whose wave lengths are greater than 6000 Å.

Filter 26—Red

This filter covers the region occupied by orange and red in the spectrum. The upper limit of the filter lies close to 6000 Å, where transmission by pure water is 85; this transmission rapidly declines as wave length increases and at 7500 Å it becomes less than 9 (fig. 9). Under these conditions the transmission of filter 26 never rises as high as do those of the others, which represent regions of high transmission in pure water. The maximum value observed is 68 in Crystal and Diamond lakes.

This value is much higher than it would be if the filter did not include orange as well as red in its range. Fig. 9 shows that if the cut-off of the filter had lain at 6500 Å, the upper limit of red, the maximum transmission would have been lower.

While radiation from this end of the spectrum is more rapidly absorbed by water than is that from the other end of the spectrum, it is less affected by stain and by suspended matter. It follows that in transparent lakes the transmission of radiation from filter 26 is much less than is that from the other filters; in lakes where stain and suspended matter are at a maximum the transmission of red may be higher than that of any other color. It may equal or exceed that of total radiation.

It might be expected that the transmission of filter 26 in the upper meters would show a progressive increase with greater depth. But this effect was not observed, although it was looked for. The observations showed the same kind of accidental variation as did those of radiation from other filters; and there was no case of a definite systematic increase of transmission with increasing depth.

Filter 16 Minus Filter 26—Yellow

Figure 9 shows that between the regions of the spectrum covered by filter 16 and filter 26 there is a region extending from about 5250 Å to 6000 Å and with its center near 5700 Å. It shows also that at wave lengths greater than 6200 Å there is little or no difference between the transmission of the two filters. If the reading of 26 is subtracted from that of 16 the

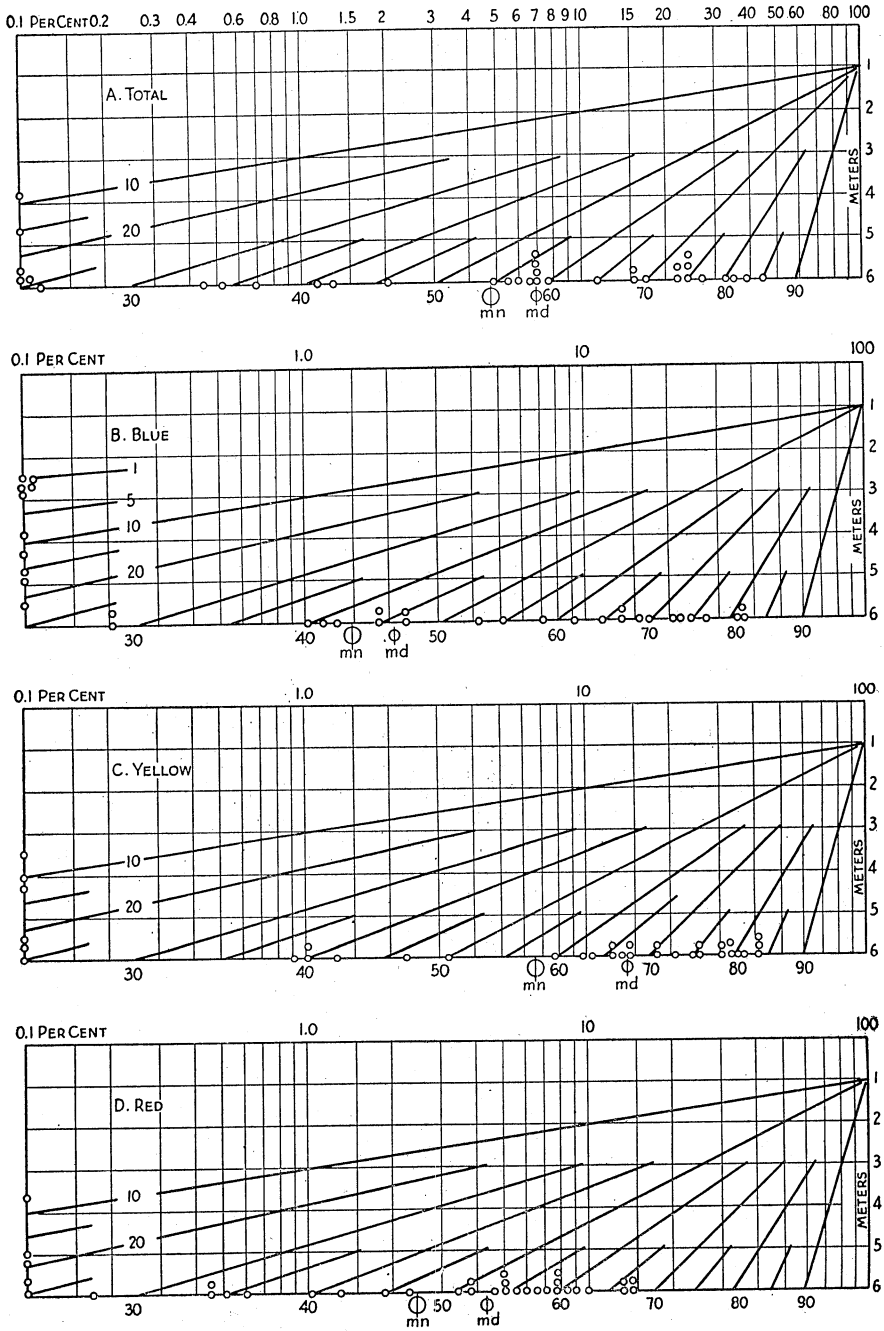

FIG. 10. Transmission of radiation in lakes observed in 1929. See p. —.
Mn, mean transmission; Md, median transmission.

remainder will show the effect of the spectral region whose center is at 5700 Å. This wave length is close to the point of maximum transmission in pure water. Since the extractive matters contained in lake waters give colors which are yellow or brown the transmission of this band is less affected by them than is that of the blue or even that of the neighboring green. Thus in very many lakes the radiation belonging to this region has a higher transmission than that from any other.

In very deeply stained waters the yellow part of the spectrum is cut off as well as that represented by green and blue, and the transmission of yellow suffers accordingly. Little Pickerel Lake, whose color is 132, shows the maximum effect of this kind. Here the transmission of yellow was doubtfully recorded as 6, on the basis of the record between 50 cm. and 100 cm. At the depth of one meter the swing of the millivoltmeter was 18 divisions of the scale for filter 16 and 17 for filter 26, showing that practically no radiation was present from the region between 5250 Å and 6000 Å.

Total and Colored Radiation in the Lakes

Table 8 and figure 10 show the general results of the study so far as the lakes are concerned. The four diagrams of figure 10 give the average transmission curves for total radiation from each lake and also for each of three colors, blue, yellow, and red. The number of cases of green is so small that they are not platted.

Figure 10 has three sets of guide lines: 1. The vertical lines of the logarithmic cycles, indicating the percentage. 2. The oblique lines, indicating transmission curves for values from 10 to 90. 3. The horizontal lines, indicating depth in meters below the surface of the lake.

The transmission curves start with 100 per cent at the depth of one meter below the surface, for reasons stated on p. 314. They are continued to the depth of 6 m. below the surface, i. e., through a thickness of 5 m. of water. At this depth the transmission curves have diverged enough to permit the arrangement of the lakes along the depth line.

Each of the small circles indicates the average transmission of one of the 34 lakes examined, either that of total radiation or of one of the colors. As already stated, this transmission

is that average found in the middle region of the lake, and is that stated in table 8. These circles are placed on the lower line of the diagram, except where transmission is so low that the curve does not reach this line. The position of the circle indicates two facts: 1. Position relative to the oblique lines; i. e., the transmission curves, indicates the observed rate of transmission, adjusted for zenith sun. 2. Position relative to the vertical lines, i. e., the per cent lines, indicates the percentage of total radiation or of one of the colors, which remains after transmission at the observed rate through five meters of water. The percentage left after passing through one meter is that stated as the transmission in table 8.

In figure 10, A, for instance, there is a circle at the end of the line indicating a transmission of 60. Table 8 shows that this represents the transmission of Muskellunge Lake. The circle lies slightly to the left of the per cent line indicating 8 per cent; more exactly, it is placed at the point indicating 7.8 per cent, since with a transmission of 60 about 7.8 per cent of the original value of the radiation will be left after passing through 5 m. of water. No particular interest attaches to these values for percentages at 5 m., which are derived by computation from the data given in table 8. They are carried out to this depth partly to get room for the distribution of lakes in the diagram, partly also to make evident to the eye the great difference in the percentage which remains, even at moderate depths, from transmissions which are not far apart. This is especially evident in the low transmissions.

The lakes are arranged in the order of their transmission and the grouping of the circles shows the different types of lake. Figure 10 A shows that there are 6 lakes whose transmission is low, i. e., below 30; an equal number come between 31 and 50; the group with high medium transmission number 13, of which 9 are closely bunched between 55 and 60; there are 9 lakes (10 cases) with high transmission, three of them between 80 and 85.

The mean transmission of the whole number of lakes is 54 and the median is about 58. The lakes examined include a larger number of clear lakes and also of highly colored lakes than would be found in the whole list of lakes in the district. The mean transmission for all lakes examined in the region is about 50.

Blue Radiation

In fig. 10 B—blue radiation—the distribution of the circles is quite different from that of the total radiation. There are 12 lakes with low transmission of blue; 10 are below 25 and 5 of them so small that the exact value is doubtful. No lakes are found in the region between 30 and 39; then come 9 lakes from 40 to 55; these represent the cluster of lakes whose total transmission is between 55 and 60 in the diagram above. There are 8 lakes at 70 and above, with 6 more between 59 and 69. Thus blue transmission tends to group at the two ends of the scale, indicating the strong influence of stain in cutting down this color, and also indicating the fact that the lakes with unstained water ordinarily have little plankton. The average transmission is 43 and the median is 46, both numbers lower than the figures for any other color.

Yellow Radiation

In the diagrams both for yellow and for red radiation (fig. 10, C, D), the circles indicating the lakes show a tendency to aggregate in the upper part of their range. This fact reflects the relative absence of sensitiveness to stain and to suspended matter on the part of these colors. In the case of yellow, figure 10 C, there are 15 cases where transmission is above 70, and 7 more are above 60; thus nearly 70 per cent of the lakes are at 60 and above. There are 6 lakes with low transmission; only one lake between 25 and 40, and that one at 39; only 4 lakes between 40 and 50. The mean transmission is 58 and the median 67.

Red Radiation

As already stated, the red filter transmits also the orange radiation. The circles indicating the lakes are crowded together at the upper part of the range, just as is the case with yellow, but at a much lower numerical value. There are 21 cases between 51 and 68 in the region of high medium transmission; this is nearly 70 per cent of the whole number; 6 cases show low transmission and 8 are in the region of low medium. Thus the transmission of red never reaches the range of "high", the fact being due to the opacity of water itself to long wave radiation. The mean transmission is 47 and the median 53.

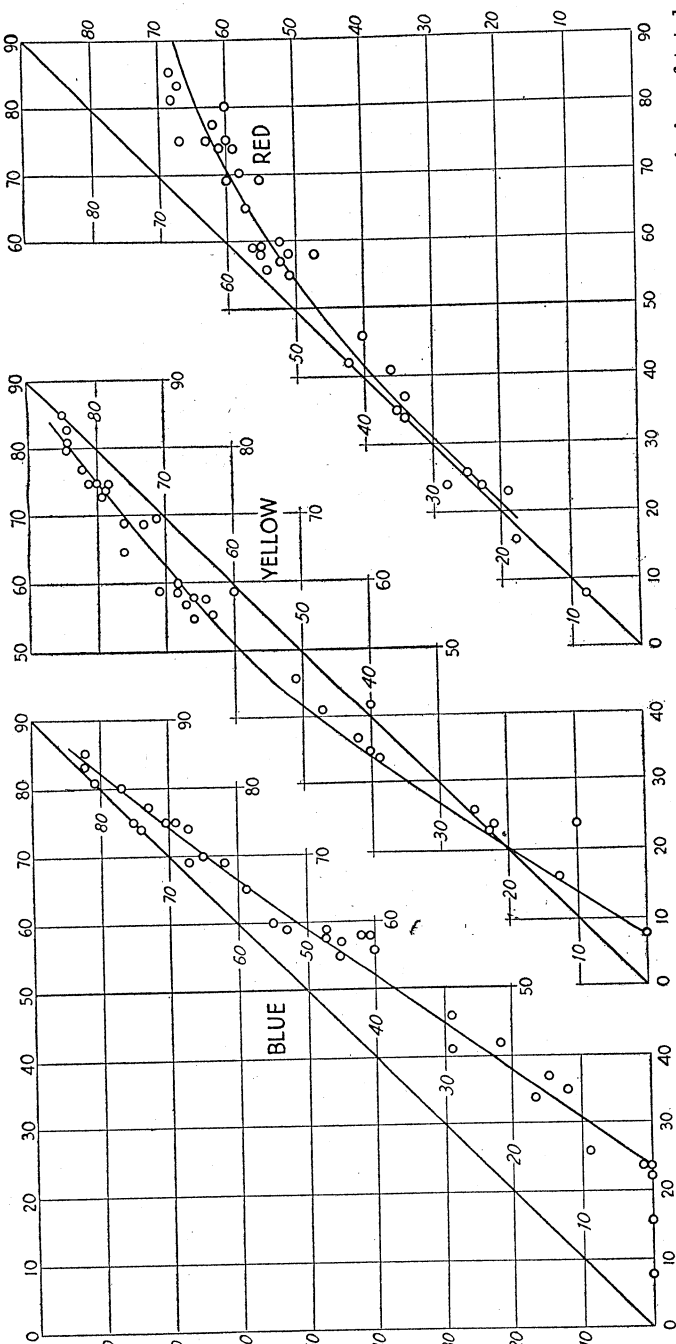

FIG. 11. Relation of transmission of spectral regions to that of total radiation. Abscissas indicate transmission of total radiation; ordinates, that of color. See p. 325.

Transmission of Total Radiation Compared with That of Colors

The transmission reported for the total radiation at any depth in the lake is necessarily equal to the weighted average of the transmissions of the radiation contained in the several regions of the spectrum, from violet or blue to red. In all cases transmission of some regions of the spectrum is above the average which constitutes that of the total, and in other regions it is below. The relation between the transmission of any spectral region and that of total radiation differs in different lakes, as the conditions of transmission are different. From these relations may be inferred the changes in the quality of the light, as it passes downward through the water of the lake.

Figure 11 shows the relation between the transmission of the total visible spectrum through the water at depths below one meter and that of the several colors of the spectrum. The figure contains three diagrams whose network is made to overlap in order to bring them on the same page, where they may easily be compared. In each of the three the transmission of one of the colors in each lake is platted against that of the total radiation in the same lake; the abscissas representing the transmission of the total and the ordinates representing that of the color. A circle is placed at the intersection of the two lines for each lake. An oblique line is drawn through each diagram as the axis. If the transmission of the color in any lake is equal to that of the total, the circle for that lake falls on the axis; if the transmission of the color is higher, the circle lies to the left or above the axis; if lower, it lies to the right or below. In each diagram a line roughly representing the mean of the observations, is drawn through the circles. This is not intended to show a mathematical relation but to furnish a guide to the eye in reading the story.

Figure 11 shows that the transmission of blue is ordinarily less than that of total; occasionally equals it; but does not rise above it. In lakes whose transmission of total is 25 or less that of blue is very small, practically negligible; and in such lakes blue makes no appreciable contribution to radiation below one meter's depth. As transmission of total rises that of blue gradually approaches it, though the average always remains below it. It becomes nearly equal to that of total at transmissions of 75 or above. Red at low transmissions is equal to or above

total; as transmission increases that of red falls below total, and the disparity increases as transmission goes up. Yellow starts somewhat below total; soon equals it; rises above it between 30 and 40; the excess rising at first and then declining in the higher orders of transmission, until at 75 and above the transmission of yellow is approaching that of total from above as that of blue is approaching it from below.

Thus these diagrams make clear the general story of the changes in the composition of the sun's radiation as it passes through the waters of lakes belonging to the several types. In lakes with deeply stained water and correspondingly low transmission, very little radiation which comes from wave lengths smaller than 6000 Å is present below one meter. The contribution of blue to the total is negligible; that of green is very small and rapidly disappears as depth increases; so also does that from the adjacent part of yellow. As total transmission rises to moderate values both blue and red also increase, but the central part of the visible spectrum—about 5500 Å—has a much higher transmission than either end; so that the radiation after passing through a few meters of water, contains very little from the blue or the red end, though red contributes more than blue. The radiation that remains is almost wholly derived from the central region of the spectrum. In the most transparent lakes. contributions from the blue increase relatively to those from red. In such lakes the short wave half of the spectrum contributes much at all depths, and radiation from the whole region, extending to wave length 5700 Å, is transmitted through the water at much the same rate.

Two examples may be given. In Crystal Lake at the depth of 20 m,—assuming average transmission to that depth—blue, with a transmission of 82 would still retain 1.8 per cent of its surface value; yellow (transmission 84) retained 3.0 per cent; while red and orange, taken together, whose transmission is 68, would be reduced to 0.045 per cent of their value at the surface. Thus at all depths in that lake, there would be enough radiation from blue to be effective chemically or physiologically.

In Trout Lake, on the other hand, at the same depth blue and red (transmission 53 and 55) would each retain respectively 0.0003 and 0.0006 per cent of their value at the surface; while yellow (transmission 68) would still retain 0.045 per cent. Thus the middle of the visible spectrum in this lake

would retain at 20 m. nearly 100 times as much of its value at the surface as would be kept by radiation from either end, and this preponderance of the middle of the spectrum increases rapidly with increase of depth.

Special attention may also be called to the group of 9 lakes whose total transmission lies between 55 and 60. In all cases the transmission of the several colors shows a wider variation than does that of the total. In yellow and red, the range extends over about ten points; from 47 to 57 in the case of red, and from 60 to 71 in that of yellow. On the whole, however, the 9 lakes constitute a well marked group in both colors, one lake being decidedly below the other 8. The case of blue is different; the range is greater, 40–55 and the lakes are scattered along the range. Table 8 shows that in this group of lakes there are three whose water has a color of 6 to 8, and six whose color is 11 to 20. The waters whose transmission of blue is below 50 belong to the second group. The situation shows how the transmission of all parts of the spectrum is affected by color and by seston; but that short wave radiation is much more strongly affected and especially by color.

The following table shows roughly the relation of transmission of total spectrum and that of its parts. The number of cases is still so small that the results should not be regarded as finally determined; the table shows the general situation; increased knowledge may modify details both in the classification of transmissions and in the range of comparative values.

TABLE 9—*Relation of transmission of colors to that of total radiation; the transmission of total being taken as 100% in all cases; that of colors is stated as a percentage of total*

Transparency, m.	1.4–2.9	2.7–3.5	3.5–7.6	6.9–12.2
Color	45–132	10–45	0–20	0–4
Transmission of total	Low	Low Medium	High Medium	High
	8–30	31–50	51–70	71 and over
Total	100%	100%	100%	100%
Blue	Very small	50–66	60–90	80–100
Yellow	50 or less	100–115	100–117	100–110
Red	100–120	90–100	80–98	70–90

COLOR TRANSMISSION IN SINGLE LAKES

The general statements made on the preceding pages are illustrated by a series of diagrams showing transmission in

single lakes. These diagrams put before the eye the average transmission of total radiation, and of the several colors in lakes representing each type of transmission, by more than one case. They disclose at a glance the points of general agreement of lakes that belong in the same group and also some of their manifold differences. The curves are carried out far enough to show the differences in transmission and also to bring out the way in which even a small increase in depth accentuates the effect of very moderate differences in rate of transmission.

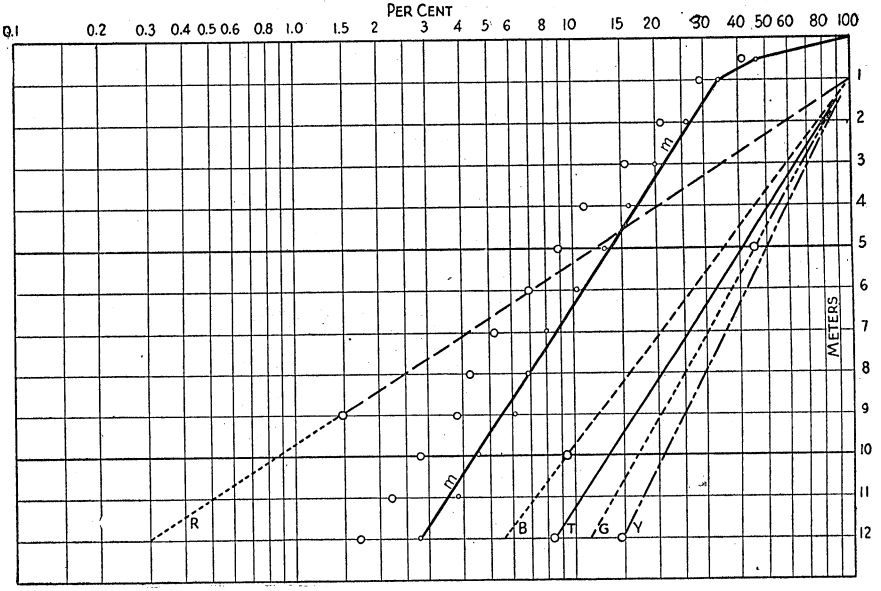

FIG. 12. Transmission of total radiation and of spectral regions in a lake with high transmission, Clear Lake, July 30, 1929. M, transmission of total referred to value of total radiation incident on surface of lake; T, total, referred to value of total at depth of one meter. Circles indicate observed per cent; smaller dots, per cent adjusted for zenith sun; larger circle on each line indicates depth to which observations extended. As in all cases, green was observed in a separate series of readings; and the observations were limited by time, not by extinction of radiation. B indicates blue; G, green; Y, yellow; R, red. See p. 329.

Figures 12–15 show the transmission of color and of total radiation in individual lakes; figures 12 and 13 give the full story of transmission, so far as it was followed, in two lakes—Clear and Clear Crooked. The first is a transparent lake with high transmission; the second has high medium transmission.

Fig. 15 shows in a similar way the record of five lakes with low medium and low transmission. Figure 14 gives diagrams from 8 lakes, four with high transmission and four with high medium transmission. These 8 diagrams are carried out only through one cycle of the logarithmic paper, or to the depth of 6 m.–8 m., as the rate of transmission may determine.

In each diagram there is platted also the transmission of total radiation as based on the value of that received in the air. These are the same curves as those shown for two of the lakes in figs. 2 and 7. In figs. 12 and 13 the observed percentages are platted, as well as the result of adjusting them for zenith sun; thus is made clear the kind of variation and of regularity present in the total transmission, which is also found in that of the colors. In each of the lakes there is placed a larger circle on each transmission curve to indicate the depth at which observation ended. In fig. 14 many of the lines pass out of the diagram before this depth has been reached.

In the observations on colors the reading at one meter is taken as 100 per cent, both for total and for each color, for reasons given on p. 314. The reading of total at one meter and based on the value in air, is considered as 100 per cent and transferred to the same point as that where the transmission curves for colors start. Thus a second transmission curve for total radiation originates at this point and runs parallel to that extending downward from the value found in the main line at one meter.

The diagram for Clear Lake (figures 12, 14 B) and those of figure 14, A, C, D, show the conditions in transparent lakes with high transmission. The conspicuous features in these lakes are: 1. The relatively low transmission of red, with its correspondingly rapid disappearance from the energy spectrum. 2. The close agreement of the high transmission of blue, green, yellow, and total; that of blue being always less than that of green and yellow. In Clear Lake the transmission of blue is distinctly lower than that of total; while in Crystal and Weber lakes the two were so close that separate lines could not be drawn. In the last named lakes green lies below yellow, though still above total. In Star Lake, where blue is decidedly lower than in the other three lakes, green coincides with total just as blue does in more transparent lakes. This situation is what would be expected in a lake whose transparency is not of

the highest. Other similar situations could be pointed out in the diagrams of the figures; but the conditions governing transmission are so numerous and so variable that more observations are needed before general statements are finally made.

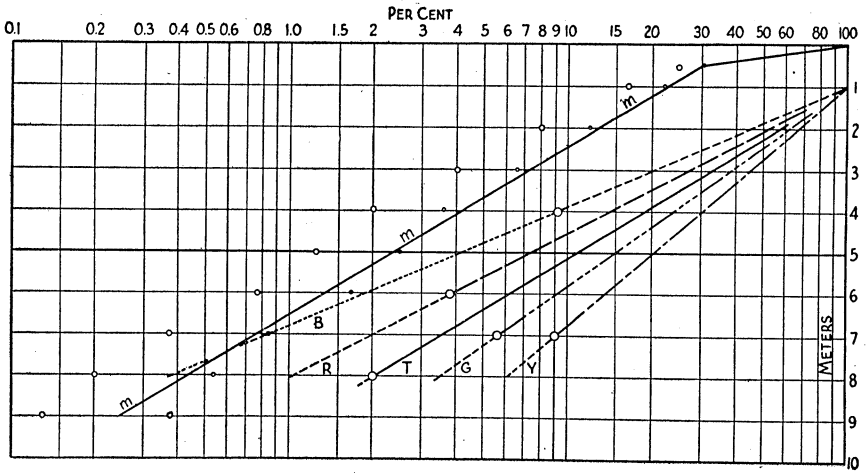

FIG. 13. Transmission curves for a lake with high medium transmission, Clear Crooked Lake, Aug. 19, 1929. Letters and signs as in fig. 12. See p. 330.

Clear Crooked Lake shows a transmission which is classed as high medium, being about 57 for total radiation. The differences between this lake and Clear Lake are due both to transparency (Clear, 9.3 m.; Clear Crooked, 4.3 m.) and to color (Clear, 0; Clear Crooked 16). The result is to reduce transmission of radiation of all kinds, but in very different degree. Transmission of total is 80 in Clear Lake and 57 in Clear Crooked, a loss of 23 points or about 29 per cent; among the colors red shows least difference; it declines from 60 to 52, a loss of 8 points, or about 13 per cent; yellow falls off about 20 per cent, from 84 to 67; green loses 24 per cent, 82 to 62; while blue loses over 40 per cent, since its transmission is 77 in Clear Lake and only 45 in Clear Crooked Lake. This relation between a lake with high transmission and one with high medium transmission is characteristic for the two groups. It shows the sensitive response of short wave radiation to both stain and suspended matter in the water.

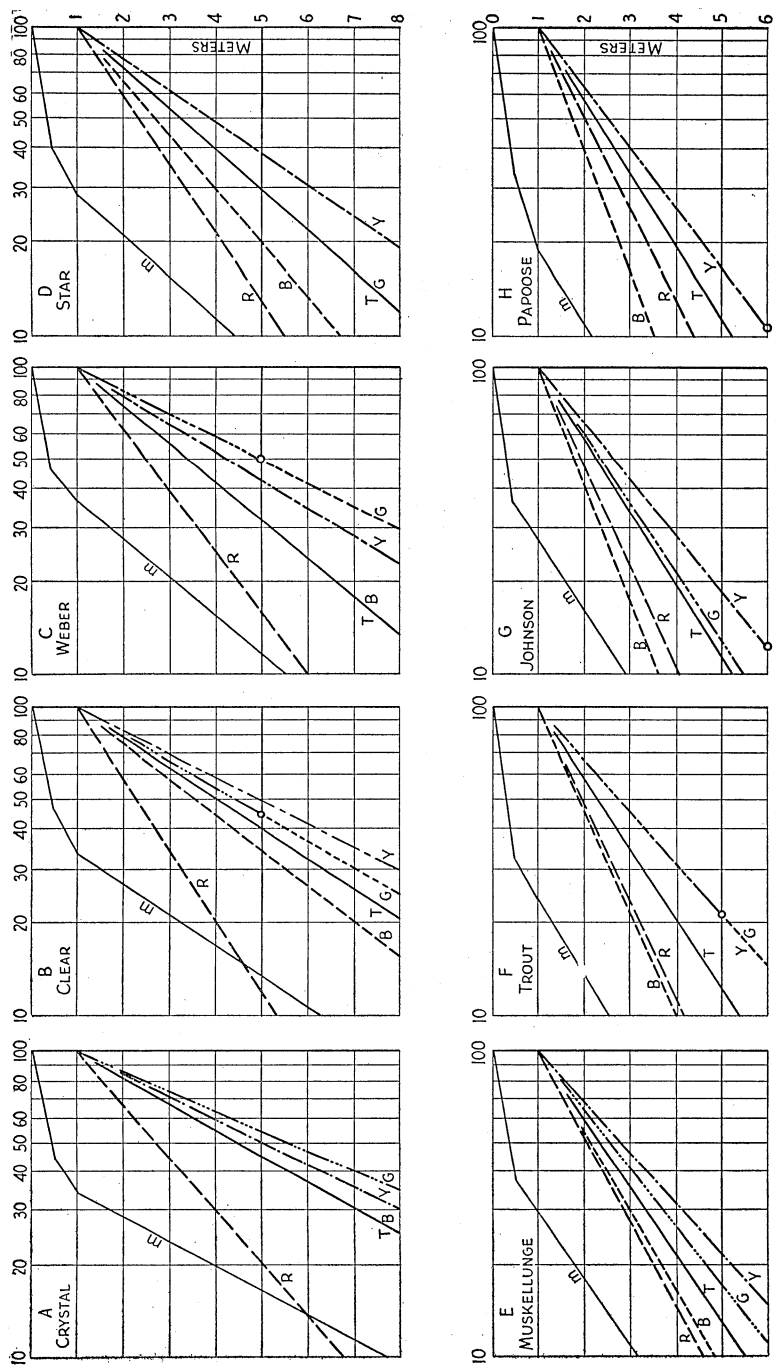

FIG. 14. Transmission curves of four lakes with high and four with high medium transmission. Letters and signs as in fig. 12. In figs. A to D note wide divergence of red from other regions and from total; the agreement between blue and total especially in figs. A and C; the relative position of blue, yellow, and green. In diagram B, although transmission of total is about the same as in diagrams A and C, that of blue is lower. In Star Lake, whose transmission of total is about the same as that of Weber Lake, blue finds much more difficulty in passing through the water; green and total are practically the same; blue as well as red is so far below total that their contributions to total radiation decline rapidly with depts and soon become negligible.

Diagrams E to H include lakes with high medium transmission much like Clear Crooked Lake, fig. 13, but with differences of detail. Note that in diagram E red has a smaller transmission than blue, while the relation is reversed in the other lakes. Green and yellow have transmission above that of total; that of red falls off less than that of any other color, when compared with the situation in high transmission lakes; hence, as transmission of total declines it approaches that of red.

Figure 14, E–H shows the same general situation in other lakes with high medium transmission. That of total radiation is between 55 and 60. Radiation from the two ends of the spectrum shows a transmission which is low and is quite similar. In Muskellunge Lake that of red is lower than that of blue; in the other cases blue is below red. In all cases green and yellow are near together and are above total. All of these lakes come from that group of nine whose transmission of total lies between 55 and 60.

Figure 15 A–E shows the transmission in five lakes; two of these, Long and Adelaide, are from the low medium group; and three, Bragonier, Midge, and Mary from the group with low transmission. Long Lake (transmission 46) belongs in the upper part of the low medium group and Adelaide Lake (transmission 35) is in the lower part of the same group. Bragonier Lake is near the top of the division with low transmission, while Lake Mary is near the bottom, so far as our observations go.

Long Lake retains the general characteristics of the high medium group, though in a reduced form. The contributions of energy from the middle of the spectrum dominate increasingly as depth becomes greater; red and especially blue fall off rapidly and the transmission of red is below that of total.

In Adelaide Lake the transmission of green has followed blue to a place below that of total. Total and red, which of course here includes orange, are the same; while yellow is still above total. Such a condition is probably typical of many lakes with a low medium transmission that is due chiefly to stain.

Among the lakes with low transmission, Bragonier still retains a measurable amount of blue in the 1–2 m. stratum; in the other two lakes the amount was too small for accurate measurement. In Bragonier Lake the transmission of yellow, red, and total were practically the same. The decline in transmission, as compared with that of Adelaide Lake, is due to the greater absorption of yellow, and the consequent removal of the position of maximum transmission toward the red end of the spectrum. In Midge and Mary lakes red was above total and yellow below it. No measurement of green was attempted in Bragonier or Midge lakes; in Lake Mary its value was close to that of yellow.

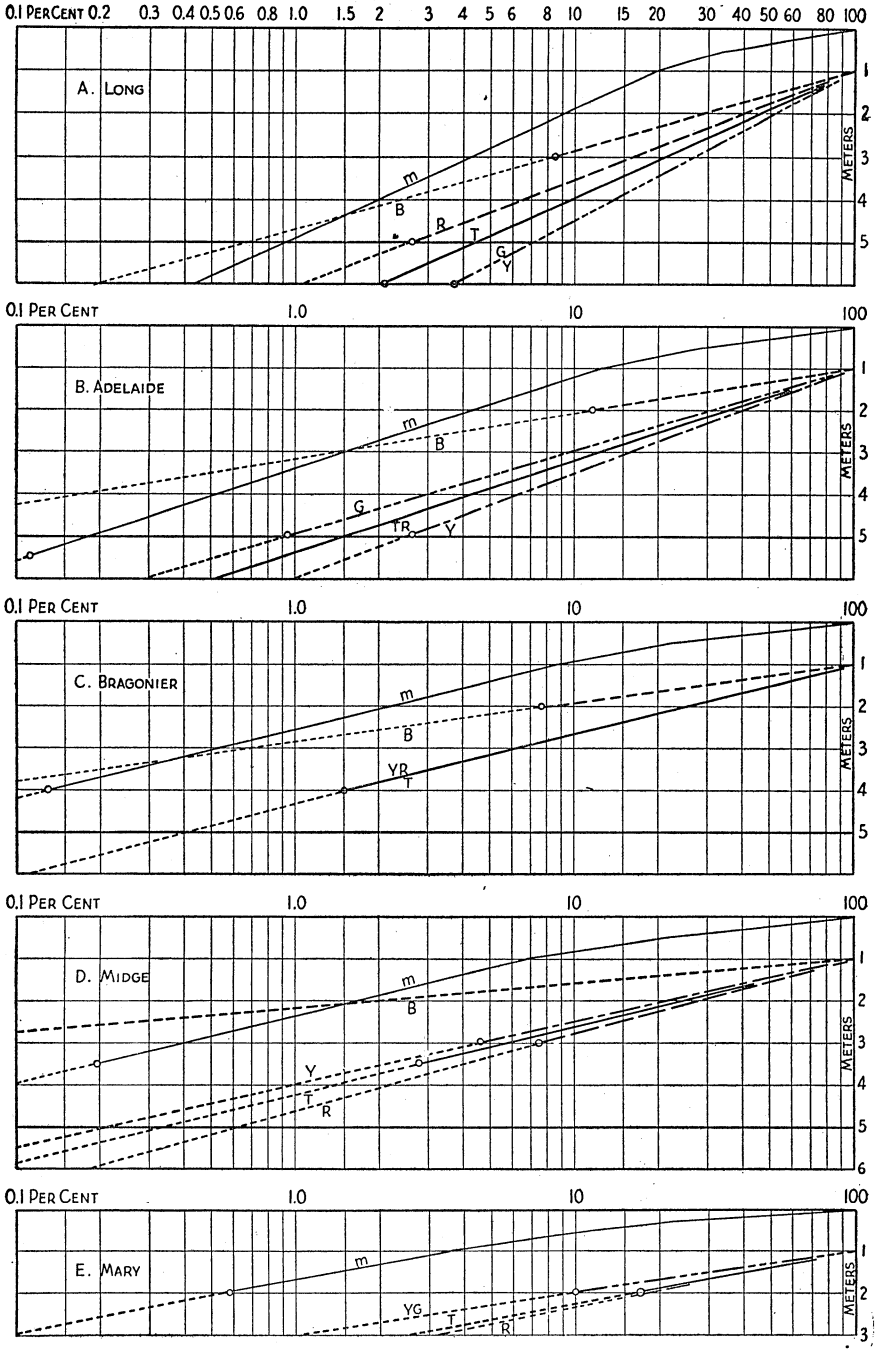

FIG. 15. Transmission curves of 5 lakes with low medium and low transmission. These are carried out through 2 or 3 logarithmic cycles in order to make the situation more clear. Letters and signs as in fig. 12. Long Lake is close to the upper limit of low medium transmission and Adelaide Lake is near the lower limit. See p. 332 for discussion. In Bragonier Lake yellow and red practically coincide with total; blue is very small; green was not observed. In Midge Lake red is slightly above total and yellow below it. In Lake Mary the same situation is seen at a lower level of transmission. If the curve for Little Pickerel Lake had been diagrammed only a single line could have been used. Total and red coincided; blue and yellow were absent or doubtful; green was not observed but could not have been present in quantity to be noted.

The series of lakes illustrated in figures 12–15 begins with the most transparent lake, Crystal, and ends with Lake Mary, one of the most opaque. It shows how at one end of the scale the energy of the visible spectrum in the water at very moderate depths is derived almost wholly from the short wave part. All portions of this from blue to yellow fairly maintain their relative contributions to the total light; while orange and red diminish rapidly and finally almost disappear as depth increases. As stain and, probably, also seston increase, the contributions to light from the blue end of the spectrum fall off and the middle of the visible spectrum becomes dominant. In lakes whose water is still more deeply stained, the short wave part of the spectrum is absorbed even more rapidly, and this absorption extends to the greater wave lengths; orange and red, rather than yellow, become the chief elements in the light. In such cases transmission is necessarily low since water itself rapidly absorbs radiation at this end of the visible spectrum. Light in observable quantity penetrates only a small distance into the lake.

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THE HIGHLAND LAKE DISTRICT OF NORTHEASTERN WISCONSIN AND THE TROUT LAKE LIMNOLOGICAL LABORATORY

C. JUDAY AND E. A. BIRGE

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

INTRODUCTION

Inland bodies of water are found in considerable numbers throughout about three-quarters of the state of Wisconsin. There are approximately three thousand of these lakes and lakelets shown on the various county maps and many others have been found which are not indicated on these maps. The latter is true especially in the northern part of the state where the original surveys were not made accurately. Including these additional bodies of water, it seems probable that there are upwards of four thousand inland lakes within the borders of the state.

In size these bodies of water range from lakelets with an area of a hectare (2.5 acres) or less up to Lake Winnebago which has an area of 557 square kilometers (225 square miles). Winnebago, however, is very much larger than any of the other inland lakes; Lake Poygan with an area of 44 square kilometers (17 square miles) is second in size and Lake Mendota with an area of 39 square kilometers (15 square miles) is third.

The great majority of the lakes that have been sounded are relatively shallow, ranging from two or three meters (7 to 10 feet) up to 15 or 20 meters (50 to 65 feet) in depth; only a few of them reach or exceed 30 meters (100 feet) in depth. Green Lake with a maximum depth of 68 meters (223 feet) is the deepest inland lake in the state and Lake Geneva with a maximum depth of 43 meters (142 feet) ranks second. Very few of these lakes possess large affluents, but the great majority of them are fed either by springs or by relatively small affluents, or by both.

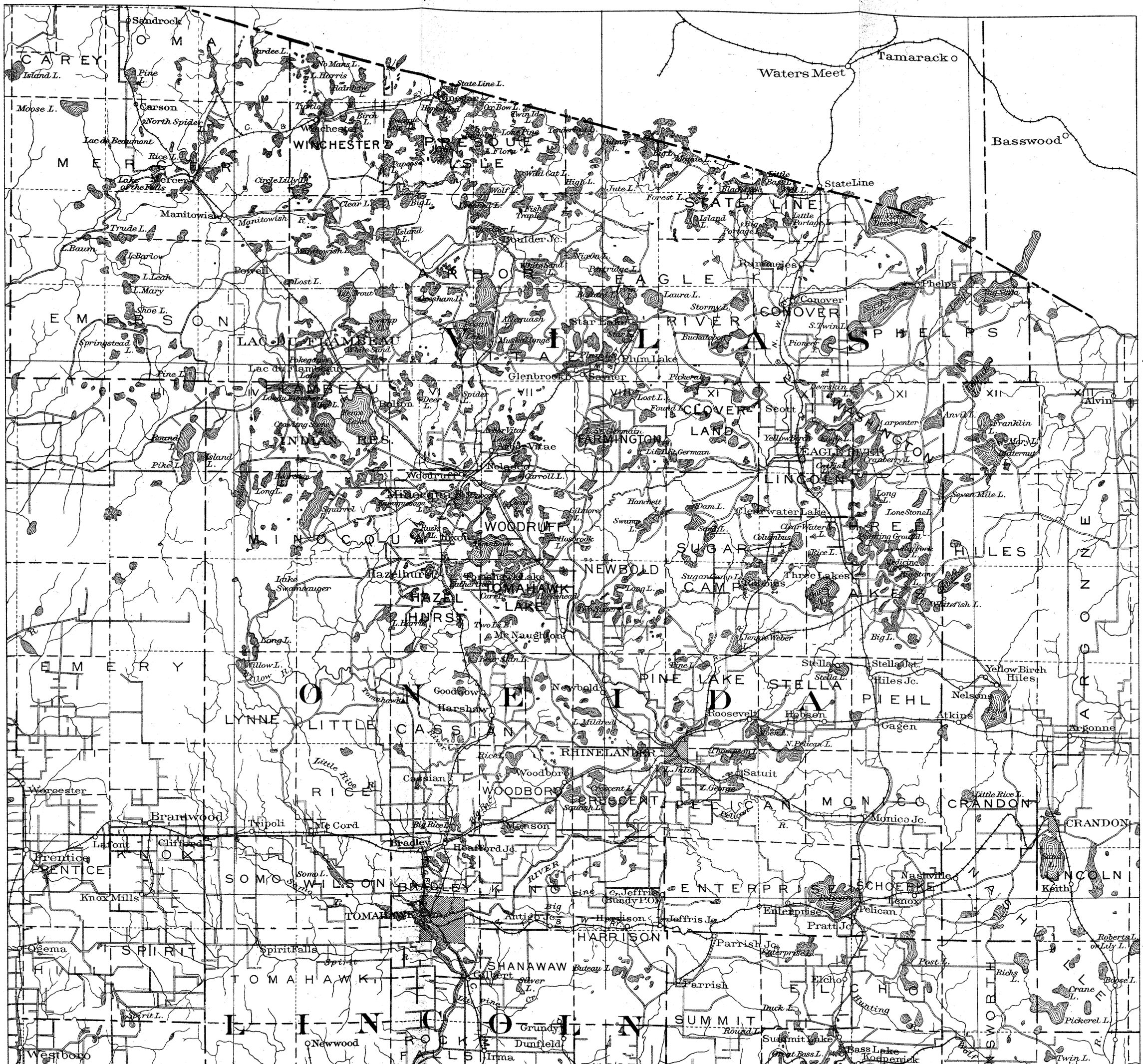
These Wisconsin lakes are glacial in origin and are confined,

therefore, to the glaciated portions of the state. During the glacial period about three-fourths of the area of Wisconsin was covered with a thick mantle of ice which moved southward from certain centers in Canada. These ice invasions were repeated at intervals, with interglacial periods of milder climate; five such invasions have been recognized. While the ice extended far beyond the southern and western boundaries of the state in some of these invasions at least, it did not cover the southwestern quarter and this section constitutes the non-glaciated or driftless area of the state; the driftless area does not possess any natural lakes.

Most of the lakes as well as the chief topographic features of glacial origin date their existence from the close of the last ice invasion which is known as the Wisconsin stage of glaciation. A belt of older drift containing lakes lies along the northern edge of the driftless area and there is also a smaller area of older drift at the southeast corner of the driftless area.

While these bodies of water form a more or less continuous chain throughout the glaciated portions of the state, they readily fall into three major groups: (1) a southeastern group extending from the Waupaca Chain near the center of the state to the southeastern corner; (2) a northeastern group situated in the northeastern quarter of the state, and (3) a northwestern group in the northwestern quarter. Several isolated lakes that do not belong definitely to either group are situated in the area between the southeastern and northeastern groups and the same is true of the region between the northeastern and northwestern groups.

A limnological study of the more important lakes in the northeastern group was begun in 1925 and this investigation has constituted the major problem of the Natural History Division of the Wisconsin Survey for the past five years (1925–1929). If present plans are carried out this investigation will be continued for another period of three to five years, perhaps longer. The present paper is intended to serve as an introduction to a series of papers which will deal with the results obtained on the various lakes of this district. Figure 1 is a map which includes practically all of the area occupied by the northeastern group of lakes. All of the lakes that have been visited up to the end of the 1929 season are situated within the region covered by the map.


Sandrock
Tamarack
Waters Meet
Basswood
CAREY
OMA
Pine L.
Island L.
Moose L.
Carson
North Spider L.
Lac de Beaumont
Rice L.
MERCER
Lake of the Falls
Mercer
Manitowish
Manitowish R.
Trude L.
L. Baum
L. Barlow
L. Leah
L. Mary
Shoe L.
EMERSON
Springstead L.
Pine L.
Lac du Flambeau
Pokegama L.
Deer L.
Spider L.
Boulton
Crawling Stone L.
Round L.
Pike L.
Island L.
Long L.
Squirrel L.
Rusk L.
Lynx L.
Willow L.
Willow R.
Goodnow
Tomahawk
Harshaw
Little Rice R.
Rice L.
Cassian
Woodboro
Worcester
Brantwood
Tripoli
Mc Cord
Lafont
Clifford
Prentice
Knox Mills
Ogema
Spirit Falls
Spirit R.
Spirit L.
Westboro
Newwood
Grundy
Dunfield
Irma
Rock Falls
Hazelhurst
Lake Swamsauger
Two Ds L.
Mc Naughton
Long L.
Newbold
Goodnow
Harshaw
L. Mildred
Rice L.
Woodboro
Bradley
Headford Jc.
Somo L.
Somo R.
Antigo Jc.
Harrison
Jeffris Jc.
Bundy P.O.
Parrish Jc.
Parrish
Elcho
Summit Lake
Bass Lake
Koepenick
Twin L.
Pickerel L.
Boose L.
Crane L.
Richs L.
Post L.
Duck L.
Round L.
Hunting Ground L.
Clear Water L.
Columbus L.
Rice L.
Three Lakes
Whitefish L.
Big L.
Jennie Weber L.
Stella
Stella Jct.
Stella L.
Hiles Jc.
Hiles
Yellow Birch
Nelsons
Roosevelt
Hobson
Gagen
Atkins
Argonne
Monico Jc.
Monico
Nashville
Keith
Lincoln
Crandon
Little Rice L.
Enterprise
Pelican
Pratt Jc.
Lenox
Schoepke
Roberts L. or Lily L.
Swamp L.
Sand L.
Dam L.
Hanchett L.
Clearwater Lake
Lone Stone L.
Severt Mile L.
Long L.
Franklin L.
Mary L.
Butternut
Anvil L.
Carpenter L.
Scott
Yellow Birch L.
Cranberry L.
Alvin
Toenkin L.
Found L.
Lost L.
Laura L.
Stormy L.
Conover
Phelps
Pioneer L.
S. Twin L.
Buckatabon L.
Star Lake
Plum Lake
Glenbrook
Sayner
Pickerel L.
Vilas
Eagle River
Eagle
Arbor Vitae
Little Arbor Vitae L.
Farmington
Little St. Germain L.
Clover
Land O' Lakes
Indian Ripples
Lac du Flambeau
Vilas
Lincoln
Oneida
Iron
Price
Florence
Forest
Langlade
Marathon
Portage
Wood
Taylor
Clark
Lynne
Little Cassian
Cassian
Rhinelander
Crescent
Pelican R.
Pelican L.
Thunderbird L.
L. Julia
L. George
Satuit
Vincent L.
Squash L.
Big Rice L.
Big Rice R.
Wisconsin River
Enterprise
Schoepke
Elcho
Summit
Sugar Camp
Newbold
Pine Lake
Stella
Piehl
Hazelhurst
Tomahawk Lake
Tomahawk
Harrison
Jeffris
Bundy P.O.
Antigo Jc.
Parrish Jc.
Pratt Jc.
Enterprise
Pelican
Lenox
Nashville
Keith
Monico Jc.
Monico
Crandon
Little Rice L.
Hiles
Yellow Birch
Nelsons
Argonne
Stella Jct.
Stella
Three Lakes
Whitefish L.
Big L.
Jennie Weber L.
Rice L.
Clear Water L.
Columbus L.
Sand L.
Swamp

A rather large upland area lying south of Lake Superior is called the Northern Highland of Wisconsin and Michigan. This Highland covers an area of about 38,850 square kilometers (15,000 square miles) in northern Wisconsin. All of the northeastern group of lakes, as well as part of the northwestern group, are situated in the Northern Highland of Wisconsin. The particular part of the Wisconsin Highland in which the northeastern lakes lie is called the Highland Lake District of Wisconsin. This lake district extends northward beyond the boundary of Wisconsin into the Upper Peninsula of Michigan for a distance of 10 to 15 kilometers (6 to 10 miles), but the lakes situated on the Michigan side of the boundary are not included in these studies. The Highland Lake District of Wisconsin covers an area of about 7,800 square kilometers (3000 square miles) but its boundaries are rather indefinite in certain sections.

The Northern Highland of Wisconsin is the highest plain in the state and the Highland Lake District comprises the highest part of this plain. In this lake district the elevations range from 457 to 548 meters (1500 to 1800 feet) above sea level, with some of the hills reaching still greater elevations. The highest hills of the district are exceeded only by Rib Hill near Wausau, which is the highest point in the state and which rises to an elevation of 591 meters (1940 feet) above sea level. Rib Hill, however, is a single peak rising about 244 meters (800 feet) above the adjacent valley of the Wisconsin River, while the hills in the Highland Lake District generally do not rise more than 30 meters (100 feet) above the surrounding plain. A broad morainic hill to the west of Crandon in Forest County reaches an elevation of 564 meters (1850 feet) and this is the second highest point in the state. A hill in the Winegar moraine has an altitude of 556 meters (1825 feet). The former hill is situated in the southeastern part of the Highland Lake District and the latter near the northern border, east of the village of Winegar. (See map, figure 1).

The elevation of the Northern Highland of Wisconsin, of which the Highland Lake District is the highest portion, is well shown by the distinctly lower elevations of the surrounding areas. To the east is Lake Michigan whose surface is 177 meters (581 feet) above sea level; to the south the elevations range from 244 to 274 meters (800 to 900 feet) and to the west

they fall to 300 meters (1000 feet) or less along the western boundary of the state; to the north of this Highland is Lake Superior with a surface elevation of 183 meters (602 feet).

The elevation of the Highland Lake District of Wisconsin, which comprises the northeastern group of lakes, is well shown by the fact that many streams have their sources within this area. It is significant also that these streams belong to three different drainage systems and flow out of this region toward the four cardinal points of the compass. The eastern part of the district drains into Lake Michigan through the Menominee, Peshtigo, Oconto, and Wolf rivers. By far the largest part of the district lies within the Mississippi Basin and drains to the south and to the west through the Wisconsin, Tomahawk, and Flambeau rivers and their tributaries. A relatively small area along the northern edge of the district drains into Lake Superior through the Montreal, Presque Isle, and Ontonagon rivers.

The streams in this northeastern lake district are still in a youthful stage as the valleys in which they flow are not very wide or deep. A considerable number of the lakes and lakelets in the district do not possess an inlet or an outlet, so that they may be regarded as strictly autotrophic in character.

Formerly this northeastern lake region was covered with a dense forest, chiefly pine with a considerable amount of hardwood in certain parts, but only a relatively small part of the virgin forest remains uncut at the present time. A large part of the cut-over land is now covered with second growth timber. A park, called the Northern Forest State Park, was established in Vilas County in the main part of the lake district in 1925; this park has an area of 538 square kilometers (208 square miles). The state owns 324 square kilometers (125 square miles) of this park land which is being held as a forest reserve and reforesting operations are now in progress on this state land.

Historical

In the period from 1905 to 1910 a quantitative study of the gases dissolved in the waters of Wisconsin lakes was made. While this investigation dealt chiefly with the lakes in the southeastern quarter of the state, more or less extended studies of the important lakes in the other two districts were carried out.

Approximately 150 lakes in the three groups were included in this investigation.

In 1911 an extensive study of the quantity and chemical composition of the standing crop of plankton of the lakes in the vicinity of Madison was undertaken and this work was continued until 1917. These lakes belong to the southeastern group. Upon the completion of this plankton study, a chemical and biological investigation of Green Lake was begun in 1921 and was continued until July 1924. This lake was selected for investigation because it is the deepest lake in the state; it is one of the more isolated members of the southeastern group. Up to the present time only a brief summary of this investigation has been published.

In 1924 it was considered desirable to extend these limnological studies to lakes in the Highland Lake District, or the northeastern group, and in accordance with this plan a preliminary survey of a number of them was made in August of that year. This preliminary survey showed that these lakes vary widely in their chemical and biological characteristics and this led to the formation of plans for a more extended study of the more important lakes in this group. In pursuance of this plan a summer limnological laboratory was established on Trout Lake in June 1925.

Trout Lake was selected for the location of the laboratory for several reasons. It is the deepest lake in the northeastern group and it is also next to the largest in size. It is located in the midst of a large number of lakes that can be reached easily by automobile from this point. The Forestry Headquarters of the Wisconsin Conservation Commission are located on the shore of Trout Lake and buildings that were not in use during the summer were generously placed at our disposal for temporary laboratories.

Trout Lake is situated near the center of Vilas County and this county alone possesses 347 bodies of water that are large enough to be shown on the county map. The combined area of these lakes equals more than 15 per cent of the total area of the county. During the progress of this investigation a number of lakes have been found which are not shown on this map, so that the county probably has as many as 400 lakes. Oneida, which is the neighboring county on the south, possesses 264 lakes according to the latest map. In addition to these lakes in

Vilas and Oneida counties, 328 lakes are situated in the five counties which border on these two counties, so that a total of about a thousand lakes is found in these seven counties.

Location

Most of these lakes lie between the meridians of 89° and 90° west longitude, and the parallel of 46° north latitude passes through this region just a short distance south of Trout Lake; most of them lie between 45° 30′ and 46° 15′ north latitude. As indicated above about two-thirds of these lakes are situated in Vilas and Oneida counties. To the east of these two counties, this lake district extends over into Forest County from 10 to 30 kilometers (6 to 18 miles) and southeastward to the middle of Langlade County. It extends southward about 10 kilometers (6 miles) into Lincoln County, while on the west it occupies a small part of the northeast corner of Price County and the east third of Iron County.

Area and Depth

In area the lakes and lakelets in this group range from a hectare or less up to 1934 hectares (2.5 acres or less to 4781 acres). Lac Vieux Desert, with an area of 1934 hectares (4781 acres), is the largest lake in the district and Trout Lake is second with an area of 1683 hectares (4160 acres).

During the progress of this investigation, 479 of the bodies of water in this lake district have been visited once or oftener and observations made on them. So far no lake has been sounded completely, but a few general soundings have been made in each of these lakes in order to obtain some idea of the approximate maximum depth. The results obtained in these cursory surveys show that the depth ranges from a minimum of one meter (3 feet) to a maximum of 35 meters (115 feet) in Trout Lake. The great majority of those that have been sounded do not exceed 10 to 12 meters (33 to 40 feet) in depth and only 35 of the 479 lakes reach or exceed 18 meters (60 feet) in depth. These deeper lakes are listed in table 1.

Glacial Geology

The glacial geology of the region around Trout Lake was studied by Thwaites (1929) in the autumn of 1927. A brief

TABLE 1. *A list of the lakes in the northeastern district having a maximum depth of 18 meters (60 feet) or more*

Lake	Area		Depth	
	Hectares	Acres	Meters	Feet
Adelaide	23	56	21.0	69
Anderson	21	53	19.5	64
Big	429	1,062	18.5	61
Big Carr	129	320	22.8	75
Black Oak	189	467	26.0	85
Catfish or Statenaker	109	268	23.0	75
Clear	373	922	28.0	92
Crawling Stone	647	1,600	28.3	93
Crooked (Flambeau)	161	397	22.0	72
Crystal	37	91	20.5	67
Dead Pike	156	384	25.0	82
Fence	1,373	3,492	28.5	93
George	28	70	21.5	70
Ike Walton	524	1,293	18.5	61
Katinka	110	276	18.5	61
Little Trout	388	960	28.0	92
Long (Phelps)	402	992	28.0	92
Mary (Adelaide)	1	3	22.5	74
Muskellunge	375	927	20.0	65
Nokomis or Swamp	198	488	22.0	72
Pallette	82	203	19.0	62
Papoose	207	512	19.5	64
Presque Isle	764	1,888	29.0	95
Silver	59	145	18.5	61
South Two	124	307	21.0	69
Star (Manitowish)	108	269	18.0	60
Star (E. of Trout)	466	1,152	18.0	60
Stone (Crandon)	342	845	23.3	76
Stormy	200	493	20.0	65
Tomahawk	1,476	3,648	22.5	74
Trout (North Basin)			26.5	87
Trout (South Basin)	1,683	4,160	35.0	115
Two Sisters	368	909	19.5	64
White Sand	321	794	20.5	67
Yawkey	44	109	21.0	69

consideration of his findings will contribute to a better understanding of the area under consideration. His survey covered approximately 1352 square kilometers (522 square miles), with Trout Lake situated near its center. (See map, figure 1).

This region is one of low relief since local differences of elevation exceeding 15 meters (50 feet) are not at all common; on the other hand extensive flats are rare. All of the topographic features were formed during the last or Wisconsin period of glaciation. Various features show that the ice moved toward the southwest in this locality, about S. 35° W. In general the northern part of the area surveyed is the roughest and local differences of elevation amounting to 23 meters (75 feet) may be found there. The southern part of the area is less rugged and it consists of a broken plain with small hills and ridges rising above the general level.

The elevations of the lakes in the surveyed area range from 477 to 518 meters (1565 to 1700 feet); the surface of Trout

Lake is 493 meters (1618 feet) above sea level. So far as known the highest hill within the surveyed area reaches an elevation of 556 meters (1825 feet).

The thickness of the glacial deposit in this region varies from 39 to 71 meters (129 to 234 feet); the underlying rock consists of schist and gneiss in the northern part of the region that was surveyed and granite in the southern part. Only three outcrops of rock have been noted so far in Vilas County.

The drift deposits of the surveyed area are divided into the following classes: (a) outwash, (b) terminal (recessional) moraines, (c) drumlins, (d) ground moraine, and (e) eskers. Of these the first or outwash covers by far the largest part of the region and the second forms the most conspicuous topographic features and the most striking country. The other features cover only a small part of the region surveyed.

The outwash belongs to the pitted type and the material consists principally of horizontally bedded sand with scattered pebbles and a few boulders. The pits or kettles are so numerous in some places that little or no upland is left between the depressions; in other places fairly large areas may be almost or quite devoid of pits. Many of these kettles extend below the water table and hence contain lakes or marshes; most of the lakes in this region were formed in this manner.

Apparently the glacial period ended in this area by a rather rapid retreat of the ice front, interrupted by at least three halts which resulted in the formation of three moraines. These have been designated the Muskellunge, the Boulder, and the Winegar moraines, named in their order from south to north. The Muskellunge moraine is situated to the south and west of Muskellunge and Trout lakes. (See figure 1). The Boulder moraine lies to the north and west of Trout Lake. Both of these moraines are relatively small in size. The Winegar moraine covers a large area in the northern part of the surveyed district and several lakes occupy basins within its boundaries; Crab, Horsehead, Presque Isle and Turtle lakes are the more important ones.

Some drumlins were found in the region to the west and northwest of Trout Lake. No true ground moraine was noted, but an area to the southeast of Papoose Lake has that appearance and it was mapped as such. An esker was noted some distance to the northwest of the village of Boulder Junction;

also a ridge of coarse gravel to the west of Crawling Stone Lake may be an esker, but it was doubtfully classified as moraine.

The shores of most of the lakes are relatively low and they are made up of the usual glacial material, such as sand, gravel and boulders in various proportions. Some of the smaller bodies of water have passed to the bog stage in which there is an outer margin of low marshy bog with a larger or smaller area of open water in the center; various stages of these bog formations are found. The water of these bog lakes and lakelets contains a certain amount of vegetable extractives derived from the bog deposit, so that it has a brown color. The same is true of the waters of lakes that receive drainage from marshes. A few of the lakes that have been visited do not show any brown coloration whatever, but the great majority of them show it in varying degrees up to a maximum of 300 as measured on the platinum-cobalt scale used by the U. S. Geological Survey; the color exceeds 100 in only a relatively small number of them.

TABLE 2. *This table shows the maximum, minimum and mean annual temperatures at nine stations of the U. S. Weather Bureau that are situated within the northeastern lake district. Taken from the summary of climatological data for the United States, by sections, Central Wisconsin. Weather Bureau, 1922. C. = centigrade and F. = Fahrenheit degrees*

Station	No. of years	Maximum		Minimum		Mean	
		C.	F.	C.	F.	C.	F.
Big St. Germaine Dam	10	37.8	100	—42.8	—45	4.2	39.6
Deerskin Dam	11	38.4	101	—43.3	—46	3.3	38.0
Koepenick	28	37.8	100	—41.1	—42	5.0	41.0
Long Lake	13	39.4	103	—45.5	—50	3.7	38.7
Minocqua	17	37.2	99	—44.4	—48	4.4	39.9
Rest Lake	8	36.1	97	—45.5	—50	3.9	39.1
Rhinelander	13	36.7	98	—40.5	—41	4.7	40.5
Tomahawk	8	36.7	98	—41.7	—43	5.2	41.4
Vudesare	10	37.8	100	—44.0	—47	3.2	37.8

CLIMATE

Temperature. The Highland Lake District of northeastern Wisconsin is situated in the north temperate zone and it is so far inland that it possesses a continental climate. Lakes Superior and Michigan undoubtedly modify the climate to a certain extent because the extremes of temperature are not as great in the lake district as they are in the same latitude fur-

ther west. The winters are cold and the summers warm; the prevailing winds are westerly. Table 2 shows the range of temperatures at several stations of the U. S. Weather Bureau that are located inside the lake district. No data obtained since 1920 are included in the table; they are taken from the tables published by the Climatological Division of the U. S. Weather Bureau, 1922.

The maximum summer temperature ranges from 36.1° C. (97° F.) at Rest Lake dam to 39.4° C. (103° F.) at Long Lake which lies southeast of the city of Eagle River. The minimum temperature varies from —40.5° C. (—41° F.) at Rhinelander to —45.5° C. (—50° F.) at Long Lake and Rest Lake dam. The mean annual temperature at the various stations falls between a minimum of 3.3° C. (38° F.) at Deerskin Dam and a maximum of 5.2° C. (41.4° F.) at Tomahawk.

The shallower lakes in this group usually become covered with ice by the middle of November, while the larger and deeper lakes do not freeze over until about the first of December. In the spring the ice disappears about the first of May; the shallower lakes usually lose their covering of ice a few days before the larger and deeper lakes. The dates of freezing in the autumn and opening in the spring are dependent upon the general condition of the weather and they vary within certain limits from year to year. The temperature of the surface water varies in the different lakes in summer; it ranges from a minimum of about 19° C. (66° F.) in some lakes to a maximum of 27° C. (80° F.) in others.

Precipitation. Table 3 shows the maximum, minimum, and the mean annual precipitation at the weather stations within this area. The mean annual precipitation is taken from Miller's table (Trans. Wis. Acad. 25: 141. 1930). The maximum and minimum amounts of precipitation, as well as the average depth of the snow, are taken from the tables published by the Climatological Division of the U. S. Weather Bureau, 1922.

The maximum precipitation at the various stations shown in the table ranges from 118.1 centimeters (46.5 inches) at Koepenick to 90.9 centimeters (35.8 inches) at Long Lake. The minimum precipitation varies from 42.9 centimeters (16.9 inches) at Minocqua to 70.3 centimeters (27.7 inches) at Rest Lake. The mean annual precipitation ranges from 73.1 centimeters (28.7 inches) at Long Lake to 82.0 centimeters (32.3

inches) at Koepenick. At most of the stations shown in this table there was an unusually small precipitation in 1910 and an unusually large one in 1911.

TABLE 3. *This table shows the maximum, minimum and mean annual precipitation and the mean annual snowfall at the nine stations of the U. S. Weather Bureau situated in the northeastern lake district. The maximum and minimum precipitation and the snowfall data are taken from the summary of climatological data for the United States, by sections. Central Wisconsin. Weather Bureau, 1922. The mean annual precipitation is after Miller.* (Trans. Wis. Acad. Sci. 25: 141. 1930)

Station	Maximum		Minimum		Mean		Mean annual snowfall	
	Centimeters	Inches	Centimeters	Inches	Centimeters	Inches	Centimeters	Inches
Big St. Germaine Dam	106.4	41.9	50.5	19.9	76.9	30.3	130.0	51.2
Deerskin Dam	92.9	36.6	44.1	17.4	77.7	30.6	106.9	42.1
Koepenick	118.1	46.5	58.4	23.0	82.0	32.3	164.0	64.6
Long Lake	90.9	35.8	47.0	18.5	73.1	28.7	131.0	51.6
Minocqua	103.1	40.6	42.9	16.9	77.4	30.5	122.9	48.4
Rest Lake Dam	93.5	36.8	70.3	27.7	77.9	30.7	124.2	48.9
Rhinelander	107.7	42.4	46.2	18.2	76.9	30.3	123.7	48.7
Tomahawk	91.7	36.1	59.4	23.4	78.7	31.0	93.7	36.9
Vudesare	99.6	39.2	48.3	19.0	81.0	31.9	196.3	78.3

This lake district lies within the region which receives from 65 per cent to 70 per cent of its precipitation during the six warmer months of the year; that is, April to September inclusive. The winter precipitation is in the form of snow and the last two columns in table 3 show that the average snowfall at the various stations ranges from 93.7 centimeters (36.9 inches) at Tomahawk to 196.3 centimeters (78.3 inches) per annum at Vudesare.

LABORATORIES

Temporary buildings were used as laboratories during the summers of 1925, 1926 and 1927. In 1928 the Wisconsin Conservation Commission gave the Survey permission to use two wooden buildings on the shore of Trout Lake for permanent laboratories. These two buildings were remodeled and a third wooden building was erected between them with a grant of money from the Brittingham fund. These three buildings were used as laboratories during the summers of 1928 and 1929. Figure 2 shows a sketch drawing of the buildings and the sur-

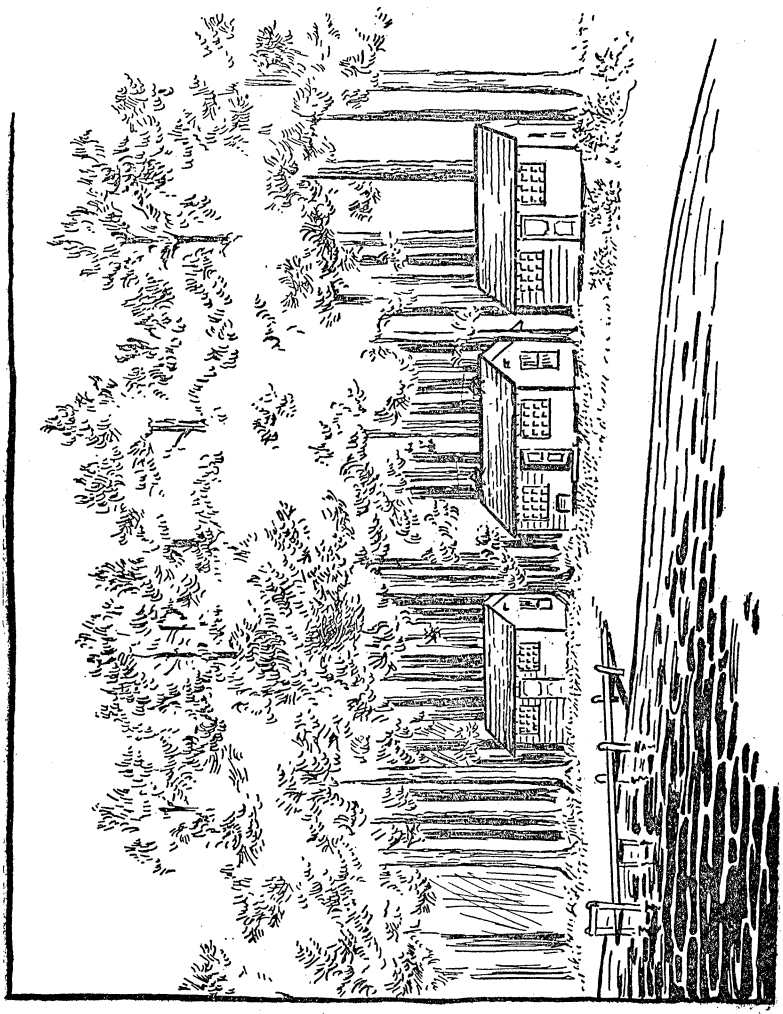


FIG. 2. Sketch of laboratory buildings.

rounding forest. They are situated at the edge of the virgin pine forest which covers the shore of the lake at this point.

The buildings are very serviceable but of inexpensive construction. The investigations will probably be continued in this lake district for a number of years, but it may be found desirable to transfer the work to another lake district of the state at some future date. In view of this fact therefore, it is not the plan to develop a more permanent type of laboratory at Trout Lake at the present time.

Figure 3 shows the general arrangement of the grounds and the plans of the buildings. The middle building (B) faces S. 40° W. The two end buildings (A and C) are 4.6 by 6 meters (15 by 20 feet) in outside dimensions, while the middle building (B) is 4.9 by 6.7 meters (16 by 22 feet). Building C is used for the chemical laboratory. A permanent table along the rear wall is equipped with running water and Pyrofax gas for the chemical work. The gas tank (G) is located at the west end of the building and the water tank (W) at the east end. The latter is mounted on a platform 2.4 meters (8 feet) above the ground and a small gasoline engine is used for pumping lake water into the tank.

Building A is used for the biological laboratory. It is equipped with four work tables, a typewriter table and a number of shelves.

The middle building (B) is divided into two rooms. The smaller room (R, figure 3) is used for evaporating samples of lake water in order to obtain residues that are used for more extended chemical analyses. A low bench along the west side of the room supports the five kerosene stoves on which the water samples are evaporated. The larger room contains the electric power plant (E) which is a Kohler farm plant of 1500 watt capacity; the electric furnace and the electric centrifuges are operated by means of this plant. The centrifuging is done on a heavy table especially made for that purpose. The drying, weighing and ashing of the centrifuge catches are done in this room.

The laboratories are equipped with deep sea thermometers, pyrlimnometers, a solarimeter, a pyrheliometer, tow nets, plankton nets, plankton traps, a bottom towing dredge, Ekman and Petersen dredges, sieves for sifting bottom material, a Dionic water tester, water samplers, a Sharples super-centri-

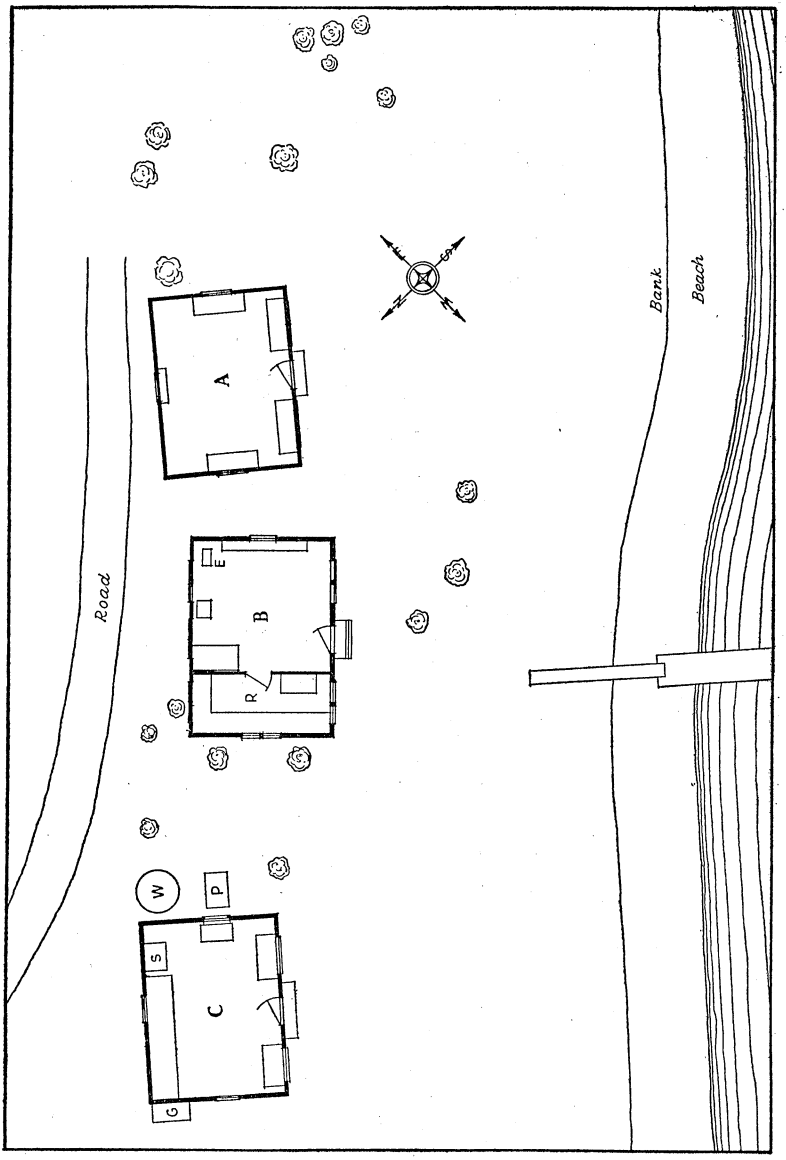


FIG. 3. General arrangement of the laboratory grounds and the plans of the buildings. A, Biology building; B, centrifuging and evoparting building; C, chemistry building; G, gas plant; W, water tank; S, sink; P, pump R, evaporating room; E, electric power plant.

fuge, two Foerst centrifuges, three row boats, one canvas boat, one rubber (Flato) boat, two outboard motors, two boat trailers and three Ford cars.

During the summer of 1925 the field staff consisted of three biologists and one chemist; in 1926 two biologists and two chemists; in 1927 five biologists and four chemists; and in 1928 and 1929 seven biologists and three chemists. In addition to the individuals engaged in the field work, a staff of three or four chemists has been employed in the chemical laboratory of the University of Wisconsin during the summers of 1927, 1928 and 1929. They were engaged in making chemical analyses of the residues obtained from the various lakes.

The United States Bureau of Fisheries has cooperated in all of the work that has been done at the Trout Lake station. During the summers of 1927 and 1928, the Bureau collected about 8,000 specimens of fish of different species from a few of the typical lakes of the region for the purpose of determining the age and the rate of growth of the fishes in the different lakes, but this work was discontinued in 1929. The material in hand, however, is now being studied for the purpose of making a report on it. A paper dealing with the rock bass material has already been published (Wright, 1929).

The field work includes physical, chemical and biological observations on the lake waters. The following physical determinations are made: temperature, transparency, color, transmission of solar radiation, conductivity, and residue upon evaporation. The chemical data include hydrogen ion concentration, free and fixed carbon dioxide, dissolved oxygen, free ammonia, organic, nitrite and nitrate nitrogen, soluble and total phosphorus, chloride and silica. The biological work includes a quantitative study of the net and centrifuge plankton, and of the bottom fauna; plankton material is also obtained with the centrifuge for the purpose of making a study of its chemical composition and thereby gaining some knowledge of its food value.

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THE ROTIFER FAUNA OF WISCONSIN. V

THE GENERA EUCHLANIS AND MONOMMATA

FRANK J. MYERS

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

Introductory note by the author. Due to the sudden and unexpected death, late in 1928, of my friend and collaborator, Mr. Harry K. Harring of Washington, D. C., no attempt has been made at an extended revision of the genus Euchlanis; the time and labor necessary for such an undertaking, unaided, are not at my disposal. Only the various species seen and studied, alive or preserved, are described and figured. A number of new species belonging to the genus Monommata are added.

INTRODUCTION

A certain degree of confusion has long existed in the determination of species of the genus Euchlanis. This was due, partly to indifferent descriptions, also to the failure to recognize the variable character of the dorsal plate in certain species, and to the absence of a true ventral plate in others. Hudson and Gosse did not agree on the structure of the ventral plate; Gosse thought that *Euchlanis deflexa* and *Euchlanis pyriformis* had no ventral plate, but had a slightly stiffened membrane in place of it. He was perfectly correct in his contention, as the ventral plates in three species are membranous and hardened at the extreme posterior portions only, without lateral flanges or lateral, longitudinal sulci connecting the dorsal and ventral plates. The variations in the dorsal plates in some of the Euchlanid rotifers are not heritable, but probably cyclic, nutritional or environmental, which is also true in many other rotifers.

Due to the extreme transparency and delicacy of the Euchlanid lorica, it is almost impossible to convey, by means of a drawing, or figure, a life-like impression. Therefore, certain liberties have been taken, in a diagramatic way, in order to

make the figures as understandable as possible. The outlines of the stiffened cuticle of the loricae have been indicated in heavier lines than the rest of the drawing. In the figures of the trophi, the unci are shown somewhat flattened in order to give a better idea of the shape and number of teeth.

As the anatomy is quite uniform throughout the genus, no attempt has been made to describe it in detail, except in the type species, *Euchlanis dilatata,* and in certain other cases where found necessary.

There are two general types of trophi running through the series of Euchlanids. In one type the tips of the rami are produced into long, slender, incurved rods without any denticulation on the inner edges; in the other, and more numerous type, the tips of the rami are much shorter, abruptly incurved, acutely pointed and have a minute pair of denticulate combs, one on the inside of each tip.

Ehrenberg made use of the foot-setae in order to separate the species. As these setae are very delicate and liable to be broken off or injured, they should not be considered as specific characters, although mentioned in the descriptions. The different species can be readily distinguished by other ascertainable differences.

The shape of the anterior margin of the dorsal and ventral plates is of little value in the determination of species; they are of soft, flexible cuticle and vary in shape with the state of contraction of the individual. There is always a sub-square notch in the middle of the anterior edge of the dorsal plate in fully contracted specimens. This is constitutional and necessary to make room for the large dorsal antenna while the rotifer is withdrawing its head.

Appreciating the fact that the genus Euchlanis is composed of a small number of relatively homologous species, there seems to be no necessity for a division into distinct genera among such closely related forms. However, there seems to be a need of some synthetic rearrangement of species, as the genus can be divided into well marked sections.

De Beauchamp recognized the need of sub-genera in certain cases and proposed the name Dipeuchlanis for *Diplois propatula* Gosse. Following his suggestions, the genus is now further divided into the sub-genera DAPIDIA, to include *Euchlanis pyriformis* Gosse, *Euchlanis deflexa* Gosse and *Dapidia calpidia,*

new species. For *Euchlanis plicata,* the sub-genus TRIPLEUCHLANIS is proposed.

Genus EUCHLANIS Ehrenberg

Euchlanis, EHRENBERG. Abh. Akad. Wiss. Berlin (for 1831), 1832, p. 131.

Rotifers with illoricate, retractile head and loricate body, truncate in front, rounded posteriorly, oval or ovate in outline. Lorica of two plates, dorsal and ventral. Dorsal plate arched and convex, larger than ventral, sometimes variable in height and shape. Ventral plate nearly flat, smaller all around than the dorsal plate. These plates are connected by thin, flexible cuticle forming lateral, longitudinal and posterior sulci. Foot with two or three obscure joints; foot glands robust; accessory foot glands present. One or two pairs of long setae are situated on the dorso-distal portion of the penultimate foot-joint; they are rarely missing in living specimens, but are apt to be broken off in preserved material. Toes two; long or short, stout or thin, fusiform or parallel-sided. Corona family type. Mastax modified malleate. The rami are roughly triangular, diminishing near the tips into acute, incurved points. The tip of each ramus carries a minute, denticular, comb-like process situated on the inside edge. There are four or five club-shaped functional teeth in each uncus that diminish in size dorsally. There are generally several non-functional accessory teeth attached to the opposing dorsal teeth near their bases. An undeveloped tooth is frequently directly attached to the outside edge of each first or ventral opposing tooth. Eyespot single, situated on, or near, the posterior end of the ganglion. Retrocerebral sac greatly developed with indications of subcerebral glands. Dorsal antenna large, truncate, with a sensory tuft of cilia in a shallow central depression. Each lateral antenna has a tuft of two or three sensory setae that emerge from small tubules, one on each side of the body in the lumbar region.

The males resemble the females but are much smaller, and the alimentary tract, including the manducatory organs are wanting.

The Euchlanids are littoral rotifers living among aquatic plants of lakes and other permanent bodies of water. Food consists of diatoms, desmids, algae and particles of organic detritus.

Subgenus DAPIDIA Gosse

Dapidia GOSSE, Journ. Royal Micr. Soc., 1887, p. 364.

Euchlanid rotifers with illoricate, retractile head and loricate dorsal plate, truncate in front, rounded posteriorly; oval, ovate or orbicular in outline. There is no true ventral plate, the membrane connecting the lateral edges of the dorsal plate being only slightly stiffened in the position of the ventral plate of the genus Euchlanis. There are no longitudinal lateral sulci. Foot with two joints; foot glands robust; accessory foot-glands present. One or two pairs of long setae are situated on the dorso-distal end of the penultimate foot-joint. Toes two, long or short, stout or slender, fusiform or parallel-sided. Corona family type. Mastax modified malleate type with prominent dorsal salivary glands. The tips of the rami are prolonged into two long, incurved, bacillar rods without denticulation on the inner edges; unci with five functional teeth. Eyespot single, situated on the posterior end of the ganglion. Retro-cerebral sac large and well developed with indications of sub-cerebral glands. The remaining anatomy resembles that of Euchlanis very closely.

Subgenus DIPEUCHLANIS de Beauchamp

Dipeuchlanis DE BEAUCHAMP, Bull. Soc. Zool. France. Vol. 35, 1910, p. 122.

Body ovoid, much compressed dorso-ventrally. Lorica of two plates, the dorsal being concave or nearly straight, obtusely pointed posteriorly and much smaller than the ventral, which is convex and rounded behind. The cuticle connecting the two plates is in the form of a deep groove, and divides the body cavity into two unequal portions, of which the ventral is much the larger and contains the greater part of the organs. The lateral edges of the two plates are nearly parallel and somewhat elevated. The foot is short and slender, without setae on the penultimate joint. The toes are long, very slender, cylindrical, parallel-sided and slightly swollen at the bases.

The head is large and is connected with the anterior edge of the lorica by a stiffened cuticular membrane. The face is inclined ventrally. The corona is of family type.

The mastax is modified malleate type. The unci each have

ten or more long, slender teeth. The rami are triangular and carry on the inside of each tip a very minute denticular comb.

The remaining anatomy is similar to that of Euchlanis.

Subgenus TRIPLEUCHLANIS Levander

Euchlanis plicata LEVANDER, Acta Soc. Fauna Fennica. 1894, p. 48, pl. 2, fig. 27.

Euchlanid rotifers, the only known species being marine.

Lorica ovoid in shape, truncate in front, rounded posteriorly. The dorsal and ventral plates are of nearly the same size; they are connected by a pair of lateral, longitudinal sulci, one pair on each side of the body; between each pair, a longitudinal flange of stiffened cuticle extends for the entire length, giving the cross-section a bellows-like appearance. The dorsal plate has a shallow posterior emargination. The foot is stout and has three joints; it is guarded by a cuticular shield-like process extending downward from the median longitudinal flanges. The foot glands and their accessories are very long. The toes are short, stout and parallel-sided, ending in rather abrupt points.

The corona is of family type.

The mastax is of the modified malleate type. There are six club-shaped teeth in each uncus; the rami are triangular and carry on the inside of each tip a minute denticular comb. The eye-spot is double and situated near the posterior end of the ganglion.

The remaining organization corresponds closely to Euchlanis.

While making no attempt to propose a general key to the Euchlanid rotifers, there are certain characters possessed by groups in common; or a species may have one or two salient characters, the mention of which will be found helpful.

Dorsal plate variable, a cross-section may resemble the arc of a circle or be triradiate, as in *Euchlanis dilatata* and *Euchlanis meneta.* The dorsal plate may be deep or shallow and the lateral edges may be pinched in or plain, as in *Dapidia calpidia;* or may have wing-like lateral expansions, as in *Euchlanis alata.*

Dorsal plate triradiate with median keel extending the entire, or nearly the entire, length: *Euchlanis callysta, Euchlanis pellucida, Euchlanis triquetra.*

Dorsal plate very high above lumbar region from which it falls away rapidly to the foot: *Euchlanis meneta.*

Dorsal plate smaller than ventral: *Dipeuchlanis propatula.*

Dorsal plate concave: *Euchlanis propatula.*

Dorsal plate with a distinct median, posterior notch: *Euchlanis dilatata, Euchlanis meneta, Euchlanis oropha, Euchlanis parva, Euchlanis phryne, Euchlanis proxima, Euchlanis triquetra, Dapidia calpidia.*

Posterior notch deep, shaped like an inverted U: *Euchlanis dilatata, Euchlanis meneta, Euchlanis parva, Euchlanis proxima, Euchlanis oropha, Euchlanis phryne.*

Posterior notch shaped like an inverted V: *Euchlanis triquetra, Dapidia calpidia.*

Posterior notch represented by a shallow emargination that varies slightly with the individual; *Dapidia deflexa, Dapidia pyriformis.*

No posterior notch: *Euchlanis callysta, Euchlanis lyra, Euchlanis pellucida, Dipeuchlanis propatula.*

Venter membranous, body without lateral flanges, or lateral longitudinal sulci: *Euchlanis callysta, Euchlanis pellucida, Dapidia calpidia, Dapidia deflexa, Dapidia pyriformis.*

Tips of rami drawn out into long, slender, incurved rods, without denticular combs inside these tips. *Dapidia calpidia, Dapidia deflexa, Dapidia pyriformis.* In the remaining species the tips of the rami are short, incurved, acutely pointed and have a pair of minute denticular combs, one on the inside of each tip. The size of these combs varies with the different species, being relatively large in *Euchlanis phryne* and very small in *Dipeuchlanis propatula,* in which species it takes careful orientation and microscopical technique to make them visible.

A cuticular shield-like process just below the posterior portion of the dorsal plate and above the first foot joint; *Euchlanis meneta, Euchlanis proxima, Tripleuchlanis plicata.*

Toes slender: *Euchlanis callysta, Euchlanis lyra, Euchlanis meneta, Euchlanis parva, Euchlanis pellucida, Euchlanis triquetra, Dapidia calpidia, Dipeuchlanis propatula.*

Toes stout, blade-like, fusiform in shape: *Euchlanis alata, Dapidia deflexa, Dapidia pyriformis.*

Toes moderate in length and fusiform in shape: *Euchlanis*

dilatata, Euchlanis oropha, Euchlanis phryne, Euchlanis proxima.

Toes short, less than the length of the foot: *Tripleuchlanis plicata.*

Toes one-third the length of the dorsal plate or longer: *Euchlanis callysta, Euchlanis meneta, Euchlanis parva, Dapidia calpidia, Dipeuchlanis propatula.*

Toes less than one-third the length of the dorsal plate: *Euchlanis dilatata, Euchlanis alata, Euchlanis lyra, Euchlanis oropha, Euchlanis pellucida, Euchlanis phryne, Euchlanis proxima, Dapidia deflexa, Tripleuchlanis plicata.*

Four functional teeth in each uncus, not counting accessories: *Euchlanis alata, Euchlanis dilatata, Euchlanis meneta, Euchlanis oropha, Euchlanis parva, Euchlanis phryne.*

Five functional teeth in each uncus: *Euchlanis lyra, Euchlanis pellucida, Euchlanis triquetra, Dapidia calpidia, Dapidia deflexa, Dapidia pyriformis.*

Six functional teeth in each uncus: *Tripleuchlanis plicata.*

Ten, or more, functional teeth in each uncus: *Dipeuchlanis propatula.*

Four lateral, longitudinal sulci; a pair on each side, divided by a longitudinal flange of stiffened cuticle: *Tripleuchlanis plicata.*

Marine in habitat: *Tripleuchlanis plicata.*

For comparison and as a help in collecting, the pH values of a number of locations, in which many of the species described were found, are here given: Atlantic County, New Jersey:—Bargaintown, 6.0 — 6.4; Gravelly Run, 4.2 — 4.4; Oceanville, 5.6 — 6.0; Lenapi Lake, 4.6 — 4.8; Indian Creek, 4.5; Cordoy Creek, 5.4 — 5.6.

Mt. Desert Island, Maine:—The Barcelona, 6.0 — 6.6; Lake Wood, 6.6 — 6.8; Trout Brook, 6.6 — 7.0; Witch Hole, 6.0 — 6.4; Upper Hadlock Lake, 6.8 — 7.0; Long Pond, 6.6 — 6.8; Jordan Pond, 6.8; Jordan Mountain Pond, 6.2; Faun Pond, 6.6; Lower Breakneck Pond, 6.6; Half Moon Pond, 6.4; Toad Hole, 6.6 — 6.8; Aunt Bettie's Pond, 6.2; Eagle Lake, 6.6 — 6.8; Bubble Pond, 6.6 — 6.8; Round Pond, 6.0 — 6.4.

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The following list of species have not been personally observed. Some of them are probably valid; they are included here for what they are worth:

Euchlanis oblonga DUJARDIN. Hist. Nat. Zooph. 1841 (Explication des planches, p. 12), pl. 19, fig. 4.

Euchlanis brachydactyla SCHMARDA. Denkschr. Akad. Wiss. Wien. vol. 7, 1854, p. 18, pl. 3, fig. 2.

Euchlanis conica SCHMARDA. Neue wirbell. Thiere, 1859, vol. 1, p. 57, pl. 13, fig. 119.

Euchlanis tetradon SCHMARDA. Neue wirbell. Thiere, 1859, vol. 1, p. 57, pl. 13, fig. 118.

Dapidia stroma GOSSE. Journ. Royal Micr. Soc. 1887, p. 364, pl. 8, fig. 6.

Dipeuchlanis elegans WIERZEJSKI. Bull. Int. Acad. Sci. Cracovie, (for 1892), 1893, p. 406.

Euchlanis cristata DADAY. Term. Fuz. vol. 25, 1902, p. 204, pl. 2, fig. 1.

Euchlanis elongata WEBER. Mus. D'Hist. Nat. 1918, Cat. Invert. Suisse. Fas. 2, Rotateurs, p. 181, text fig.

Euchlanis longobardica MANFREDI. Brevi appunti rotiferologici, p. 6. fig. 2. Bollett. Pesca. Pisc. Idrob. Roma, Anno V, Fascicolo, 1.

EUCHLANIS DILATATA Ehrenberg

Pl. 10, Figs. 1–3; Pl. 11, Figs. 1–8

As this is the type species of the genus, and for the information of those who care to follow it up, there follows as complete a bibliography as was possible to gather. In the other species, except where thought necessary, a citation of the orignal description only is given.

Euchlanis dilatat EHRENBERG, Abh. Akad. Wiss. Berlin (for 1831), 1832, p. 131, pl. 4, fig. 3; Infusionsthierchen, 1838, p. 463, pl. 58, fig. 2; SCHMARDA, Kleine Beitr. Naturg. Infus., 1846, p. 49; Neue wirbellose Thiere, vol. 1, 1859,—PERTY, Zur Kenntniss kleinst. Cohn, Zeitschr. Wiss. Zool., vol. 9, 1858, p. 289, pl. 13, figs. 4–7.—Lebensformen, 1852, p. 41.—LEYDIG, Zeitschr. Wiss. Zool., vol. 6, 1854, p. 60. —MOXON, Trans. Linn. Soc., vol. 24, 1864, p. 459, pl. 47, fig. 7.—BARTSCH, Jahresh. Naturk. Württemberg, vol. 26, 1870, p. 357; Rotatoria Hungariae, 1877, p. 45.—HUDSON, Monthly Micr. Journ. vol. 8, 1872, p. 98, pl. 28, figs. 1, 2.—DADAY, Erdélyi Muz.-Egylet Evkön.,

new ser., vol. 2, 1877, p. 182; Orvos–Termész. Ertes., vol. 8, pp. 20, 201; ibid., vol. 9, 1884, p. 60; vol. 10, 1885, pp. 67, 236; Math. Termész. Ertes., vol. 3, 1885, p. 160; Wiss. Erforsch. Balatonsee, vol. 2, 1897, p. 125; Termész. Füzetek, vol. 21, Suppl., 1898, p. 15; vol. 24, 1901, p. 20; Zoologica, pt. 44, 1905, p. 107; pt. 59, 1910, p. 81; Math.–Naturw. Ber. Ungarn, vol. 26, 1913, p. 299; EYFERTH, Mikr. Süsswasserbew., 1877, p. 53, fig. 91; Einfachst. Lebensformen, 1878, p, 88, ed. 2, 1885, p. 113.—ECKSTEIN, Zeitschr. Wiss. Zool., vol. 39, 1883, p. 385, pl. 26, figs. 33–35.—PLATE, Jenaische Zeitschr. Naturwiss., vol. 19, 1885, p. 52, pl. 2, figs. 16–21.—HUDSON AND GOSSE, Rotifera, vol. 2, 1886, p. 90, pl. 23, fig. 5.—BLOCHMANN, Mikr. Thierw. Süssw., 1886, p. 108; WHITELEGGE, Proc. Royal Soc. N. S. Wales, vol. 23, 1889, p. 316.—TESSIN, Arch. Naturg. Mecklenburg, vol. 43, 1890, p. 165, pl. 2, figs. 20, 21.—PETR, Sitzungsber. Böhm. Ges. Wiss. (for 1890), 1891, p. 233.—HOOD, Scottish Natural., vol. 11, 1891, p. 77.—WIERZEJSKI, Bull. Soc. Zool. France, vol. 16, 1891, p. 52; Rozpr. Akad. Umiej., Wydz. Mat.–Przyr., Krakow, ser. 2, vol. 6, 1893, p. 239. —ANDERSON AND SHEPHARD, Proc. Royal Soc. Victoria, new ser., vol. 4, 1892, p. 77.—TURNER, Bull. Sci. Lab. Denison Univ., vol. 6, 1892, p. 60.—BILFINGER, Jahresh. Naturk. Württemberg, vol. 48, 1892, p. 116.—BERGENDAL, Acta Univ. Lundensis, vol. 28, 1892, sect. 2, no. 4, p. 115.—TERNETZ, Rotat. Umg. Basels, 1892, p. 17.—GLASSCOTT, Sci. Proc. Royal Dublin Soc., new ser., vol. 8, 1893, p. 70.—KERTÉSZ, Budapest Rotat. Faunája, 1894, p. 34.—BARROIS AND DADAY, Rev. Biol. Nord France, vol. 6, 1894, p. 399.—JENNINGS, Bull. Michigan Fish. Comm., no. 3, 1894, p. 23; Bull. U. S. Fish Comm., vol. 19, 1900, p. 90.—LEVANDER, Acta Soc. Fauna et Flora Fennica, vol. 12, no. 3, 1895, p. 47.—KELLICOTT, Trans. Amer. Micr. Soc., vol. 18, 1896, p. 163.—SKORIKOV, Trudy Obshch. Isp. Prir. Kharkovsk. Univ., vol. 30, 1896, p. 316; Ezhegodn. Volzhsk. Biol. Stants., no. 1, 1903, p. 37; Trudy Ikhtiol. Lab. Kaspiisk.–Volzhsk. Rybn. Prom., Astrakhan, vol. 3, no. 5, 1914, pp. 19, 21, 27.—HEMPEL, Bull. Illinois State Lab. Nat. Hist., vol. 5, 1898, p. 374.—WEBER, Rev. Suisse Zool., vol. 5, 1898, p. 575, pl. 21, figs. 19–22; Zool. Jahrb., Syst., vol. 24, 1906, p. 208.—STENROOS, Acta Soc. Fauna et Flora Fennica, vol. 17, no. 1, 1898, p. 158.—WESENBERG–LUND, Vid. Medd. Nat. For., 1899, p. 87, pl. 2, fig. 41; Kgl. Danske Vidensk. Selsk. Skrift., Nat.–Math. Afd., ser. 8, vol. 4, 1923, p. 273, pl. 4, fig. 1, pl. 5, fig. 5.—KIRKMAN, Journ. Royal Micr. Soc., 1901, p. 237.—ROUSSELET, Forschungsber. Biol. Stat. Plön, vol. 10, 1903, p. 175.—HILGENDORF, Trans. N. Zealand Inst., vol. 35, 1903, p. 270.—VOIGT, Forschungsber. Biol. Stat. Plön, vol. 11, 1904, p. 67.—DE BEAUCHAMP, Bull. Soc. Zool. France, vol. 30, 1905, p. 116; Arch. Zool. Expér., ser. 4, vol. 6, 1907, p. 14, figs. 8, 9; ser. 4, vol. 10, 1909, pp. 101, 124, 325, pl. 1, figs. 4, 5, pl. 4, fig. 44, pl. 5, figs. 48, 49, 63, pl. 6 figs. 65, 71, 72, text figs. VII B, LV; Bull. Soc. Zool. France, vol. 38, 1913, p. 181.—LIE–PETTERSEN, Bergens Mus. Aarbog (for 1905), 1905, no. 10, p. 37; (for 1909), 1910, no. 15, p. 61.—THALLWITZ, Ann. Biol. Lacustre, vol. 1, 1906, p. 262.—THIÉBAUD, Zool. Anz., vol. 29, 1906, p. 767.—VORONKOV, Trudy Gidrobiol. Stants. Glubokom

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As the corona of *Euchlanis dilatata* agrees with that of the other species of the Euchlanid rotifers, a general description of it will suffice for all. It is triangular in general shape; there is a small, nude apical area enclosed by the circumapical band which is reduced to a row of long cilia. On the dorsal part of the middle portion of the apical area are situated two prominent tubular, papillose prominences, at the tips of which are the duct openings of the retrocerebral sac. Near these prominences, and on the outside of each, is a small tubule from which emerge a tuft of sensory setae. On the anterior sides of the head are two arcs of long cilia specialized for propulsion; they resemble auricles but are not retractile. The buccal plate is covered with very short, close-set cilia and the mouth is at the lower extremity. The dorsal and lateral arcs of the buccal plate are strongly developed, the laterals joining under the mouth. Above the dorsal arc and below the apical area is a transverse row of long cilia disposed into three tufts on slight prominences.

The general shape of the body is ovoid, truncate anteriorly,

rounded posteriorly. The dorsal plate is variable in height and shape of the cross-section, varying from the low arc of a circle to a high triangle. The ventral plate is nearly as large as the dorsal all around and is slightly constricted anteriorly at the opening for the head; it is joined to the dorsal plate laterally by membranous, longitudinal sulci. The rounded posterior portion of the dorsal plate is divided mesially by a deep, elongate notch, shaped like an inverted U. When observing the posterior notch, the microscope should be focused on the anterior edge; by focusing down from this point, the posterior edge of the flexible membrane connecting the lateral edges of the notch will be seen. On plate 12, figure 5, the stippled area represents the flexible, connective membrane, and figure 6 shows a cross-section at the point A. This membrane appears to allow a certain amount of lateral expansion to the posterior portion of the dorsal plate. The foot is slender and two-jointed, and a pair of long setae protrude from the distal margin of the first foot joint. The toes are about one-third the length of the dorsal plate and are blade-like and fusiform in shape.

The dorsal antenna is prominent and truncate; it has a small tuft of sensory setae in a hollow central depression. The lateral antennae are in the form of small, projecting tubules, from each of which emerges a sensory tuft of setae; they are constant in shape throughout the genus. (Plate 12, figure 77).

The mastax is modified malleate in type, (sub-malleate of Hudson and Gosse). The unci have four diminishing, opposing, clubshaped, functional teeth, resting in depressions between the ridges of the rami. The large ventral teeth each have a rudimentary tooth attached for almost the entire length. There are several minute accessory teeth attached to each of the functional dorsal teeth near their base. The rami are triangular and the basal apophysis is large. The tips of the rami are abruptly reduced to very acute points carrying on the inside of each a minute denticulate comb-like process. The fulcrum is short, stout and plow-shaped.

The stomach, as is usual in the genus, is sharply constricted at the point of junction with the intestine.

The retrocerebral sac is large and well developed; it varies in size with its state of contraction, always being larger in well nourished individuals. The foot glands are medium and there are two small accessory glands that are constant in the genus.

The gastric glands, ovary, bladder and nephridial system are normal.

Measurements: Acid water forms with long dorsal plate, from Atlantic County, New Jersey. Length of dorsal plate, 270μ; length of ventral plate, 250μ; length of toes, 50μ. Width of dorsal plate, 130μ; width of ventral plate, 105μ. Depth of lorica, 90μ. Material from Newdorf, near Strasbourg, France: Length of dorsal plate, 200μ length of ventral plate, 170μ length of toes, 70μ. Width of dorsal plate, 90μ; width of ventral plate, 80μ. Depth of lorica, 95μ. Material from Vorkommen–Zangenfrund, Altwasser des Rheims: Length of dorsal plate, 250μ; length of toes, 75μ. Width of dorsal plate, 189μ. Depth of lorica in various specimens, 90μ, 105μ, 120μ, 140μ, 155μ.

Euchlanis dilatata is cosmopolitan, being found in permanent bodies of water everywhere. It is tolerant to both acid and alkaline conditions, being found in both hard and soft water. The form with the deep, triangular, dorsal plate may be easily mistaken for a small *Euchlanis triquetra.* The differences between the two species are: The dorsal plate of *Euchlanis dilatata,* in lateral view, is evenly arched, without a distinct neck region, (plate 11, figure 5); in *Euchlanis triquetra,* the dorsal plate is very high over the stomach, rising abruptly from a rather distinct neck region, then falling away rapidly towards the foot (plate 13, figure 1. *Euchlanis dilatata* never has a dorsal keel, no matter how high the dorsal plate may be; while *Euchlanis triquetra* always has a dorsal keel which may not be very evident in preserved material on account of expansion, but is always present in living animals. The posterior notch of *Euchlanis dilatata* is deep and shaped like an elongate, inverted U; while the posterior notch of *Euchlanis triquetra* is relatively more shallow and shaped like an inverted V.

EUCHLANIS PARVA Rousselet

Pl. 12, Figs. 1–6, 11

Euchlanis parva ROUSSELET, Journ. Queckett. Micr. Club, 1892, ser. 2, vol. 4, p. 396, pl. 24.

Euchlanis oropha GOSSE, Süsswasserfauna Deutschlands, pt. 14, 1912, p. 167, fig. 328.

The corona agrees with that of the other species of the genus.

The body is ovoid in shape, truncate in front, round behind. A cross-section resembles the high arc of a circle. The dorsal

plate is mesially divided posteriorly by a deep U-shaped notch. The ventral plate is nearly as large as the dorsal all around and is connected to the dorsal plate by two lateral, longitudinal sulci, one on each side. The usual pair of long setae project from the dorsal side of the first foot joint. The toes are long and slender, gradually increasing in width from the base to near the tips, from where they fall away rapidly to acute points; their length is more than one-third that of the dorsal plate.

The dorsal and lateral antennae are normal and in the usual positions.

The mastax is of the modified malleate type. There are four opposed, club-shaped, functional teeth in each uncus with several accessories attached to the dorsal teeth near their bases. The rami have a pair of minute fan-shaped, denticulate combs, one on the inner side of each tip.

The retrocerebral sac, eye-spot, and remaining anatomy are normal to the genus.

Length of the dorsal plate, 140μ; length of ventral plate, 125μ; width of dorsal plate, 100μ. Width of ventral plate, 75μ; length of toes, 70μ; depth of posterior notch, 50μ.

This species is figured and described in the Süsswasserfauna Deutschlands, as *Euchlanis oropha* Gosse.

Rousselet says that one of the distinguishing characters of *Euchlanis parva* is the large size of the lateral antennae. His specimens must have been small ones as the lateral antennae do not vary much in size with the size of the individual. A small specimen would naturally appear to have larger lateral antennae than a larger one. In fact, the tubular lateral antennae are very uniform in size throughout the genus Euchlanis.

Euchlanis parva resembles *Euchlanis dilatata* but is readily distinguished from it by its smaller size and by the very long, slender toes. It is a cosmopolitan species, being found everywhere in the littoral region of permanent bodies of water among aquatic vegetation.

EUCHLANIS OROPHA Gosse

Pl. 12, Figs. 7–10

Euchlanis oropha GOSSE, Journ. Royal Micr. Soc. London, 1887, p. 5, pl. 2, fig. 16.

The corona agrees with that of the other species of the genus.

The body is ovate in shape, truncate in front, rounded behind, and a cross-section resembles the arc of a circle. The dorsal

plate has a deep posterior notch shaped like an inverted U. The ventral plate is nearly as large as the dorsal all around; it is joined to the dorsal plate by a pair of longitudinal sulci extending the entire length of the body. The foot is stout and two-jointed. The presence of foot-setae was not determined, owing to the small amount of material available. The toes are short and stout, gradually increasing in width for about two-thirds their length then falling away to acute points; they are about one-fourth the length of the dorsal plate.

The dorsal antenna is normal to the genus and the lateral antennae are in the usual position.

The mastax is modified malleate in type. There are four, opposed, clubshaped, functional teeth in each uncus and the usual pair of denticulate, fan-shaped, comb-like processes are present, one on the inside of each ramus tip.

The retrocerebral sac, eye and remaining anatomy are normal.

Length of the dorsal plate, 200μ; length of ventral plate, 180μ; width of dorsal plate, 130μ; width of ventral plate, 115μ; length of toes, 70μ.

This species seems to be rare. The only material seen was received from the late Mr. Chas. F. Rousselet by whom it was determined. He collected it in the Grand Junction Canal, London, England.

Euchlanis oropha is closely related to *Euchlanis dilatata* from which it differs mainly in the stouter foot and more robust differently shaped toes. The tooth formula is the same in the two species, with minor differences in the accessory teeth which are probably subject to variation.

EUCHLANIS TRIQUETRA Ehrenberg

Pl. 13, Figs. 1–5

Euchlanis triquetra EHRENBERG, Infusionsth., 1838, p. 461, pl. 57, fig. 8.
Euchlanis hyalina LEYDIG, Zeitsch. Wiss. Zool. vol. 6, 1854, p. 60.
Euchlanis uniseta LEYDIG, Zeitschr. Wiss. Zool. vol. 6, 1854, p. 61, pl. 4, fig. 45.
Euchlanis triquetra hyalina, SÜSSWASSERFAUNA DEUTSCHLANDS, pt. 14, 1912, p. 168, text fig.

The corona agrees with that of the other species of the genus.

The body is ovoid in shape, truncate in front, rounded behind. The dorsal plate is triradiate in cross-section and has a high median keel extending from the neck region to the an-

terior angle of the posterior notch. The posterior notch is triangular and shaped like an inverted V. The ventral plate is about three-fifths the width of the dorsal. Longitudinal sulci of flexible cuticle unite both plates laterally. The foot is two-jointed and a pair of long setae project from the dorsal side of the first foot joint. The toes are slender, fusiform and about one-third the length of the dorsal plate.

The dorsal antenna is normal and the laterals are in the usual position.

The trophi have five functional, club-shaped teeth in each uncus and there are the usual pair of denticulate combs, one on the inner side of the tip of each ramus. The remaining anatomy is normal to the genus.

Euchlanis triquetra varies considerably in size depending on food conditions and the environment.

Length of the dorsal plate, 210 — 270μ; length of ventral plate, 180 — 240μ; width of dorsal plate, 155 — 240μ; width of ventral plate, 105 — 160μ; length of toes, 70 — 85μ; depth of lorica, 140 — 180μ.

This species is universally distributed in the littoral zone of permanent bodies of water where conditions of existence permit. It appears to be able to tolerate both acid and alkaline conditions, as we have collected it in various locations ranging in pH from 6.4 to 7.6. This is not uncommon among the rotifera as there are many species, belonging to the cosmopolitan group, that are able to tolerate a ten point range or more.

Through the kindness of Dr. P. de Beauchamp, examples of *Euchlanis triquetra* were recently received from l'Agoulmine (mare), Ikeur, Algeria, North Africa. It is interesting to note that the dorsal keel in these specimens is more reduced in the anterior portion and prominent posteriorly.

Euchlanis triquetra resembles *Euchlanis pellucida* superficially, but is consistently smaller and readily distinguished from the latter by the presence of a ventral plate. The smaller species bear a certain resemblance to the triradiate form of *Euchlanis dilatata* (plate 11, figures 4, 7). The differences are discussed in the course of the description of *Euchlanis dilatata.*

DAPIDIA DEFLEXA Gosse

Pl. 21, Figs. 1–5

Euchlanis deflexa GOSSE, Ann. Mag. Nat. Hist., London, 1851, ser. 2, vol. 8, p. 200.

The corona agrees with that of the genus Euchlanis. The body resembles the arc of a circle in cross-section. The dorsal plate is ovoid, constant in shape and without a distinct posterior notch, although there may be a shallow emargination in place of it. The lateral edges of the dorsal plate are connected by a flexible membrane somewhat thickened in the position occupied by the ventral plate in the genus Euchlanis. The posterior portion of this area is of hardened cuticle, as shown by the heavy line in figure 2. There are no lateral longitudinal sulci. The foot is stout and two-jointed; it carries two pair of long setae on the dorsal end of the first foot joint. The toes are short, stout and fusiform in shape, ending in tips that appear almost papillose in dorsal view.

The dorsal and lateral antennae are normal.

The mastax is modified malleate type. The tips of the rami are drawn out into long, slender, bacillar rods, without denticulate combs inside the tips as in Euchlanis. There are five slender, opposing teeth, clubbed at the tips, and two or three accessory teeth attached to the bases of the dorsal teeth in each ramus.

There are a pair of prominent dorsal salivary glands attached to the anterior part of the mastax. The remaining anatomy is normal.

Length of dorsal plate, 280μ; length of toes, 90μ width of dorsal plate, 125μ.

Dapidia deflexa appears to be rare in the United States. The animal, figured and described here, is from material determined by the late C. F. Rousselet, who collected it at Mill Hill, England, and stated that it agreed perfectly with specimens of Gosse's he had seen. At first glance, this species can easily be mistaken for the form of *Euchlanis alata* without the lateral wing-like expansions of the dorsal plate. Both are robust animals with stout toes and foot-glands. If it be remembered that *Euchlanis alata* has a normal, well-marked, ventral plate with lateral flanges and longitudinal sulci, and, that the type of the mastax is different from Dapidia, there will be no confusion between the two species.

DAPIDIA PYRIFORMIS Gosse

Pl. 15, Figs. 5–7

Euchlanis pyriformis GOSSE, Ann. Mag. Nat. Hist. 1851, ser. 2, vol. 8, p. 201.

The corona agrees with that of the other species of the genus.

The body is orbicular in shape, truncate in front, round behind. The lateral edges of the dorsal plate are often pinched in near the middle. The venter is membranous, only the posterior portion being stiffened; there are no lateral sulci. The foot is obscurely two-jointed and has two pairs of long setae projecting from the dorsal side of the first foot joint. The toes are short, stout and nearly parallel sided; their length is a little over one-fourth that of the dorsal plate.

The dorsal and lateral antennae are normal and in the usual positions.

There are a pair of prominent dorsal salivary glands attached to the mastax, one on each side of the opening of the oesophagus. The gastric and foot glands are stout and large. The remaining anatomy is normal.

In specimens from Epping Forest, England, kindly sent and determined by Mr. C. F. Rousselet, length of the dorsal plate, 285μ; width of dorsal plate, 275μ; length of toes, 80μ. In specimens from Karlsruhe, Baden; length of the dorsal plate, 320μ; width of dorsal plate, 315μ; length of toes, 85μ.

This species seems to be rare, having been reported from the United States several times only. It has much in common with *Dapidia calpidia* and *Dapidia deflexa.* In these three species, the type of the mastax is the same, the rami differing from Euchlanis as pointed out previously; they all have membranous venters without lateral flanges or longitudinal sulci, in place of the ventral plates as found in the genus Euchlanis; they all have prominent dorsal salivary glands arising from anterior portion of the mastax. Neither *Dapidia deflexa* nor *pyriformis* has true posterior notches, but may have slight emarginations instead, depending on the state of contraction of the individual. The lorica of *Dapidia pyriformis* is constant, so far as is known, with the middle portions of the dorsal plate always pinched in. The lorica of *Dapidia calpidia,* its nearest relative, is variable in depth and the lateral edges of the dorsal plate may, or may not, be pinched in.

DAPIDIA CALPIDIA Myers. new species

Pl. 20, Figs. 1–8

The corona agrees with that of the genus Euchlanis.

The dorsal plate is variable in cross-section; it may be high and obscurely triradiate, or round. The middle portions of the lateral edges may, or may not be, pinched in and extend downward below the venter. The sides of the dorsal plate are connected by a flexible membrane somewhat stiffened in the position of the ventral plate as in the genus Euchlanis. There are no lateral, longitudinal sulci. There is a wide V-shaped notch in the middle of the posterior margin of the dorsal plate. The foot is slender and two-jointed; it carries two pairs of long setae on the dorsal side of the first foot joint. The toes are long, slender and parallel-sided, ending in rather abrupt points.

The mastax is of the modified malleate type. The tips of the rami are drawn out into long, bacillar rods, without denticulate combs on the inner side of the tips. There are five slender, opposing teeth, clubbed at their tips, and two or three accessory teeth in each ramus.

There are a pair of prominent dorsal salivary glands attached to the mastax near its anterior part. The remaining anatomy is normal.

Length of the dorsal plate, 280μ; width of dorsal plate, 220μ; length of toes, 120μ.

Dapidia calpidia resembles *Dapidia deflexa* by the presence of dorsal salivary glands and the same type of mastax; it resembles *Dapidia pyriformis* by the presence of dorsal salivary glands and the same type of mastax and, in some cases, the same type of dorsal plate with the lateral edges pinched in. It differs from them by having long, slender toes and by the presence of a distinct posterior notch.

This may be a form of the species described by Gosse as *Dapidia stroma*. What there is of his description fits fairly well. As the description in the Supplement is insufficient for a positive determination, no mention being made of anything but the lorica, the specific name *Dapidia stroma* is not used here. *Dapidia stroma* has never been found since and it seems advisable to wait for further information on the species before definitely deciding that it is the same species as *Dapidia calpidia*.

The various forms of *Dapidia calpidia* are fairly common in bodies of permanent water of pH less than 7.0, in Atlantic County, New Jersey; Mt. Desert Island, Maine and Vilas County, Wisconsin. We have also had it from Karlsruhe and Münchweiler-Weiher, Baden, and from Heidelsiche-Waldace, Kreis Weibenfels, Germany.

Euchlanis calpidia is never found in large numbers in a collection, appearing to be a rather solitary animal. It seldom has any coloring matter in the stomach or intestine, always being clear and of a milky appearance.

EUCHLANIS PHRYNE Myers, new species

Pl. 14, Fig. 1; Pl. 15, Figs. 1–4

The corona agrees with that of the other species of the genus.

The general shape of the body is oval. The lateral edges of the dorsal plate are pinched in near the middle part and there is a deep, inverted U-shaped posterior notch, which is nearly as deep as the toes are long. The ventral plate is stiffened throughout, and longitudinal sulci connect it with the dorsal plate. The foot is two-jointed and has the usual pair of long setae projecting from the first foot joint. The toes are short, fusiform, slightly swollen in the middle portion then gradually diminishing to the tips; their length is a little over one-fourth that of the dorsal plate.

The dorsal antenna is normal and bears the usual tuft of sensory setae in a central depression. The lateral antennae are in the usual position.

The trophi have four opposed, club-shaped, functional teeth in each ramus, and there are a pair of fan-shaped, denticulate combs, one on the inner side of the tip of each ramus.

The foot glands are long and moderately stout. The remainder of the anatomy is normal.

Length of the dorsal plate, 225μ; length of ventral plate, 210μ; width of dorsal plate, 180μ; width of ventral plate, 150μ; length of toes, 65μ.

Euchlanis phryne is rare, only a few individuals having been collected in Eagle Lake and Toad Hole, Mt. Desert Island, Maine. The dorsal plate bears a superficial resemblance to *Dapidia pyriformis* and one of the forms of *Dapidia calpidia.* The species differs from them by having a true ventral plate; a deep U-shaped posterior notch and different type of trophi.

EUCHLANIS PELLUCIDA Harring

Pl. 14, Figs. 2–6

Euchlanis pellucida HARRING. Rep. Cana. Arc. Exp. 1913, vol. 8, pt. E, Rotatoria, Ottawa, 1921, p. 6, pl. 2.

The corona agrees with that of the other species of the genus. The body is orbicular in dorsal view and triradiate in cross-section. The dorsal plate is produced laterally into wide flanges, and has a high median keel extending its entire length. The venter is joined directly to the lateral edges of the dorsal plate without the intervention of longitudinal sulci. There is no posterior notch. The foot is obscurely two-jointed; two long setae project from the dorsal side of the first foot joint. The toes are long, slender and nearly straight, slightly enlarged posteriorly and end in rather abrupt points.

The dorsal antenna is large in diameter and obliquely truncate; it bears a small tuft of sensory setae in a shallow, central depression. The lateral antennae are minute tubules in the usual position.

The mastax is of the modified malleate type. There are five opposing, clubshaped, functional teeth in each uncus, with several minute accessory teeth attached to each of the dorsal teeth. The rami are triangular and the tips are abruptly reduced to acute points, on the inside of each is a finely denticulate, fan-shaped comb-like process.

Length of dorsal plate, 300 — 500μ; width of dorsal plate, 270 — 450μ; length of toes, 90 — 150μ.

Euchlanis pellucida is found in permanent bodies of water with an acid reaction of less than pH 7.0. It has been collected in Vilas County, Wisconsin; Atlantic County, New Jersey; Mt. Desert Island, Maine; Polk County, Florida; Alaska, Baden, Germany, and France.

This species bears a superficial resemblance to *Euchlanis triquetra,* from which it differs in its greater size; the absence of a ventral plate and posterior notch.

EUCHLANIS ALATA Voronkov

Pl. 16, Figs. 1–5; Pl. 17, Figs. 1–5

Euchlanis alata VORONKOV, Ann. Mus. Zool., St. Petersburg, 1912, vol. 16, p. 210, text figure.

The corona agrees with that of the other species of the genus. The body resembles an arc of a circle in cross-section, and may

have lateral wing-like expansions of the dorsal plate, as shown in figures 2 and 3 of plate 17; or may be perfectly ovoid without any signs of these expansions. Intermediate forms are common and figure 2, plate 16, shows one of these, with the lateral expansions just starting to form. There is no true posterior notch, but a slight emargination may be sometimes seen in place of it. The ventral plate is elongate and somewhat over one-half the width of the dorsal. The foot is robust and has two joints. Two pairs of setae project from the dorsal side of the first foot-joint. The toes are stout, fusiform and about one-fourth the length of the dorsal plate.

The dorsal antennae are normal and the lateral antennae are in the usual position.

The mastax is modified malleate type. The tips of the rami are acute and incurved with a pair of finely denticulate combs, one on the inner side of each tip. There are four stout functional teeth in each uncus, with several accessory teeth attached to the dorsal pair at their bases. At the dorsal point of junction of the mastax with the oesophagus, there are two pairs of what appear to be glands, one pair on each side of the oesophagus. These may be the "sessile renflenments" referred to by de Beauchamp; they are quite large, the anterior pair being much larger than the posterior pair; they contain several large nuclei indicating their glandular structure. In the genus Calpidia the pair of dorsal salivary glands are large and originate in the anterior portion of the mastax. The small glands in *Euchlanis alata,* above referred to, originate at the junction of the oesophagus with the mastax and may be gastric in their function.

The retrocerebral sac is large and well developed. The stomach and intestine have the usual strong constriction between them. The foot glands and their accessories are large and stout. The remaining anatomy is normal to the genus.

Length of dorsal plate, 260 — 280μ; length of ventral plate, 200 — 220μ; length of toes, 70 — 100μ; width of dorsal plate, 185 — 210μ; width of ventral plate, 150 — 170μ.

Euchlanis alata is common in permanent bodies of acid water on Mt. Desert Island, Maine, where it is found in all stages of seasonal or cyclic "wing" development. It has been collected in Atlantic County, New Jersey, but these specimens had no lateral wing-like processes. Specimens have been received

from near Moscow, Russia, and from Arc-en-Barrois (Haute-Marne) France.

This species, form without "wings", may easily be mistaken for *Euchlanis deflexa.* See description of *Euchlanis deflexa* for the points of difference.

EUCHLANIS CALLYSTA Myers, new species

Pl. 17, Figs. 6–9

The corona agrees with that of the other species of the genus. The body is much laterally compressed, very high dorso-ventrally and has a central keel extending the entire length of the dorsal plate. There is no ventral plate, and the membrane, taking the place of it, is joined directly to the sides of the dorsal plate without the intervention of longitudinal sulci. Only the extreme posterior portion of the venter is cuticular, as represented by the curved line in figure 7. The foot is obscurely two-jointed and two setae project from the dorsal side of the first foot-joint. The toes are long, parallel-sided and quite slender.

The dorsal antenna is unusually large in diameter and obliquely truncate; it bears the usual tuft of sensory setae in a shallow, central depression. The lateral antennae are normal and in the usual position.

The mastax is of the modified malleate type; the rami are stout and triangular, more robust at the tips than in the other species; there are a pair of very minute denticulate combs, one on each ramus just inside the tips. The two opposing ventral teeth of the unci are very stout, followed by four more slender teeth without any accessories. The remaining anatomy is normal.

Length of dorsal plate, 170μ; length of toes, 50μ; width of dorsal plate, 80μ depth of lorica, 65μ.

Euchlanis callysta is rare, always very transparent, seldom with coloring matter in the stomach or intestine; it swims through the water very rapidly and is in constant motion. It has been collected in Atlantic County, New Jersey and on Mt. Desert Island, Maine, in permanent bodies of acid water, ranging in pH from 6.4 to 6.8.

EUCHLANIS LYRA Hudson

Pl. 18, Figs. 1–5

Euchlanis lyra HUDSON, Hudson and Gosse, Rotifera, 1886, p. 89, pl. 23, fig. 1.

The corona agrees with that of the other species of the genus.

The body is elongate and ovoid. A cross-section resembles the arc of a circle. The dorsal plate is evenly arched in lateral view and there is no posterior notch. The ventral plate is about two-thirds the width of the dorsal at its widest part, and somewhat constricted near the posterior end.

The foot is slender and two-jointed and has the usual pair of long setae on the dorsal side of the first foot-joint. The toes are moderately long, very slender and nearly parallel-sided; their length is somewhat less than one-third that of the dorsal plate.

The dorsal antenna is small and bears the usual tuft of sensory setae in a shallow central depression. The lateral antennae emerge from a pair of minute tubules in the usual position.

The mastax is of the modified malleate type. The rami are triangular and carry a pair of minute denticulate combs just inside the tips, one on each ramus. The unci each have five unequal, opposing, club-shaped, functional teeth with two or three accessories attached to the dorsal teeth near their bases. The remainder of the anatomy is normal.

Length of the dorsal plate, 335μ; length of ventral plate, 225μ; width of dorsal plate, 180μ; width of ventral plate, 130μ; length of toes, 90μ.

The lateral view of this species is quite characteristic. The dorsal plate begins to fall away gradually towards the foot at a point over the constriction between the stomach and intestine, giving the animal a very shallow appearance at the posterior portion of the body.

The very slender toes, together with the absence of a posterior notch are enough to separate it from the other species of the genus.

Euchlanis lyra was collected in Silver Spring Reservoir, Los Angeles, California, by Myers, the only time reported from the United States. Specimens have been received from Herr J. Hauer who collected it at Donaveshingen, Baden, and who re-

ports it common there in the spring of the year. Dr. P. de Beauchamp kindly sent material of this species from France. The late Chas. F. Rousselet kindly sent material from Dundee, Scotland.

EUCHLANIS PROXIMA Myers, new species

Pl. 19, Figs. 1–4

The corona agrees with that of the other species of the genus.

The body is ovoid in shape. The dorsal plate is evenly arched in lateral view and has a deep U-shaped posterior notch. The ventral plate is almost as large as the dorsal all around. Longitudinal sulci of flexible cuticle join the dorsal and ventral plates. Just under the posterior notch of the dorsal plate and above the first foot-joint is a cuticular, shield-like process that evidently protects the delicate foot. The foot is two-jointed and the pair of setae that usually project from the dorsal side of the first foot joint are wanting in this species. The toes are stout and blade-shaped; their length is about one-third that of the dorsal plate.

The dorsal antenna is normal and the lateral antennae are in the usual position.

The mastax is of the modified malleate type. The trophi have four clubshaped, functional teeth in each uncus and there are a pair of denticulate, fan-shaped combs, one on the inner side of the tip of each ramus. The remainder of the anatomy is normal.

Length of the dorsal plate, 105μ; length of ventral plate, 90μ; width of dorsal plate, 105μ; width of ventral plate, 90μ; length of toes, 50μ.

This species is closely related to *Euchlanis meneta*. While the trophi are very similar and both have a protective, shield-like process above the first foot-joint, the toes of Euchlanis proxima are relatively much shorter and stouter than those of *Euchlanis meneta*; the lateral view of the lorica of *Euchlanis proxima* is evenly arched, while the lateral view of *Euchlanis meneta* is very high in the lumbar region and falls away abruptly to the foot. The dorsal plate of *E. proxima* is constant, being evenly arched in cross-section, while the dorsal plate of *E. meneta* is variable and may be evenly arched or triradiate as shown on plate 19, fig. 7, and indicated by the dotted line.

Euchlanis proxima is rare. It was collected in submerged sphagnum near the bank of an acid brook about three miles south of Tuckertown, New Jersey (pH 6.0).

EUCHLANIS MENETA Myers, new species

Plate 19, Figs. 5–8

Euchlanis oropha LUCKS, Zur Rotatorienfauna Westpreussens, Danzig, 1912, p. 105, fig. 31 (not Gosse, 1887).

The corona agrees with that of the other species of the genus. The body is roughly ovoid in dorsal view and a cross-section may resemble the arc of a circle or be roughly triradiate. The dorsal plate rises from the neck region to a point above the lateral antennae relatively higher than in any of the other species of Euchlanis, from where it falls away abruptly to the foot. The posterior notch is very deep and resembles an elongate, inverted U. The ventral plate is roughly about two-fifths of the dorsal in width and, as in the other species of Euchlanis, is connected to the dorsal plate by thin cuticle forming longitudinal sulci. It is true that the width of the lateral sulci in Euchlanis is variable, depending on the state of nourishment and the development of the ova. However, in this species the dorsoventral width of the lateral sulci is relatively uniformly wider than in any other species of the genus. Under the posterior portion of the dorsal plate and above the first foot-joint is a cuticular, shield-like process evidently protecting the delicate foot. The same structure is to be found in *Euchlanis proxima* and *Tripleuchlanis plicata.* The foot is two-jointed and very slender, with two pairs of very long setae projecting from the dorsal side of the first foot-joint. The toes are very long, slender and nearly straight, with a slight swelling near the tips; their length is nearly one-half the length of the dorsal plate.

The dorsal antenna is normal; the lateral antennae are in the usual position. The remainder of the anatomy is normal.

The mastax is of the modified malleate type. The trophi have four strong clubbed, functional teeth in each uncus and there appear to be no dorsal accessories. A minute pair of denticulate combs, one on the inside of the tip of each ramus, are present.

Length of dorsal plate, 120 — 140μ; length of ventral plate, 100 — 120μ; length of toes, 65 — 75μ. Width of dorsal plate,

80 — 100μ; width of ventral plate, 50 — 65μ. Depth of posterior notch, 35 — 45μ. In young individuals the toes are frequently equal to the remainder of the body in length.

Euchlanis meneta is common in bodies of permanent water in Atlantic County, New Jersey; Mt. Desert Island, Maine and Vilas County, Wisconsin. We have received it also from France, England and Germany. Lucks describes and figures this species, calling it *Euchlanis oropha* Gosse. Its closest relative is *Euchlanis proxima*, from which it differs in the smaller size, shape of the dorsal plate in lateral view, and the length and shape of the toes.

TRIPLEUCHLANIS PLICATA Levander

Pl. 22, Figs. 1–4

Euchlanis plicata LEVANDER, Acta Soc. Fauna, Flora Fennica. Helsingfors. vol. 12, No. 3, p. 48, pl. 2, fig. 27.

The corona agrees with that of the genus Euchlanis.

The body is ovoid in shape. The dorsal plate has a shallow emargination in the position of the posterior notch. The ventral plate is nearly as large as the dorsal all around. There are a pair of lateral, longitudinal sulci on each side of the body, that connect the dorsal and ventral plates, each lateral pair being separated by a flange of stiffened cuticle. A cross-section would look as if the dorsal and ventral plate were both connected by two bellows-like folds. There is a shield-like process above and protecting the first foot-joint, as in *Euchlanis proxima* and *meneta*. The foot is stout and has three robust joints which project considerably beyond the lorica in extended specimens. The setae on the dorsal side of the penultimate foot-joint seem to be wanting. The toes are short and parallel-sided; they are about one-third the length of the dorsal plate.

The dorsal and lateral antennae are normal and in the usual positions.

The mastax is modified malleate in type. The rami are triangular in ventral view and there are six opposing, functional teeth in each uncus. There are a very minute pair of denticulate combs, one on the inner side of the tip of each ramus.

The retrocerebral sac is relatively small. There are two closely connected eye-spots near the posterior part of the ganglion.

The foot glands and their accessories are very long and slender. The remainder of the anatomy is normal.

Length of the dorsal plate, 90μ; length of ventral plate, 100μ; width of dorsal plate, 60μ; width of ventral plate, 55μ; length of toes, 25μ.

This species is common everywhere, in the salt water of bays and inlets, wherever there is a growth of marine algae; it is the only marine Euchlanid rotifer known.

DIPEUCHLANIS PROPATULA de Beauchamp

Pl. 22, Figs. 5–7

Diplois propatula GOSSE, Hudson and Gosse, Rotifera, 1886, vol. 2, p. 87, pl. 24, fig. 2.
Euchlanis subversa BRYCE, Sci. Goss. vol. 26, 1890, p. 77, text figs.
Euchlanis elegans WIERZEJSKI, Bull. Acad. Sci. Cracovie (for 1892), 1893, p. 406.
Euchlanis longicaudata COLLIN, Deutsch–Ost–Afrika, vol. 4, no. 15, 1897, p. 6, fig. 4.
Dipeuchlanis propatula DE BEAUCHAMP, Bull. Soc. Zool. France, vol. 35, 1910, p. 122.

The corona of this species is of the family type and is ventrally inclined. The head is large and connected with the anterior edge of the lorica by a cuticular membrane.

The shape of the body is oval, truncate in front, rounded behind.

The dorsal plate is concave and smaller than the ventral plate all around, the posterior portion gradually narrowing, being obtusely pointed at the posterior end. The ventral plate is convex. The dorsal and ventral plates are connected by a deep groove that seems to be slightly more stiffened than the cuticle forming the lateral sulci in the genus Euchlanis. The lateral edges of the two plates are nearly parallel and somewhat elevated above the planes of the plates themselves.

The foot is short, slender and three-jointed; there are no setae on the dorsal side of the penultimate foot-joint. The toes are very long, parallel sided, very slender, cylindrical and slightly swollen near their bases. Individuals occur with perfectly straight toes, and with the toes curved outwards, varying somewhat in length in specimens from different locations; the average would be about one-half the length of the dorsal plate.

The dorsal and lateral antennae are of the normal Euchlanid type, in the usual positions.

The mastax is of the modified malleate type. The rami are triangular in ventral view, and the unci each have ten, or more, long, slender, teeth, clubbed at the tips. There are a pair of very minute denticular, fan-shaped combs, one on the inner tip of each ramus.

Length of the lorica, 170 — 200μ; length of toes, 70 — 110μ.

Dipeuchlanis propatula is fairly common in hard water lakes and ponds, among aquatics of the littoral region. A single individual was collected in the very acid water of Indian Creek, Ocean County, New Jersey, (pH 4.5) September, 1927. The specimen was small, poorly nourished and seemed to be accidental.

Some Important References in Which Descriptions and Figures of the Genus Euchlanis May Be Found

Hudson, C. T. and P. H. Gosse: The Rotifera or Wheel Animalcules, both British and foreign. Quarto. London, 1886. vol. 1, VI, 128 pp., 15 pls., vol. 2, 144 pp., pls. 16–30.

Hudson, C. T. and P. H. Gosse: The Rotifera or Wheel Animalcules, Supplement, both British and foreign. Quarto. London, 1889, 64 pp., pls. 31–34.

Weber, E. F.: Faune rotatorienne du basin de Léman. Revue Suisse Zool., Genéve, 1898, vol. 5, pp. 263–785, pls. 10–25.

Collin, A., Diffenbach, H., Sachse, R., and M. Voigt: Süsswasserfauna Deutschlands; Heft. 14. Rotatoria und Gastrotricha. Octovo. Jena, 1912. IV + 273 pp., text figs.

Weber, E. F. and G. Montet: Catalogue des Invertèbrès de la Suisse. Fascicule II, Rotateurs, Genéve, 1918, XII + 332 pp., text figs.

Beauchamp, P. M. de: Recherches sur les Rotifères: les formations tégumentaires et l'appareil digestif. Arch. Zool. Exp., Paris, 1909, ser. 4, vol. 10, pp. 1–140, pls. 1–9, text figs.

Genus MONOMMATA Bartsch

Monommata BARTSCH, Jahresh. Naturk. Württemberg, 1870, vol. 26, p. 344.

HARRING, H. K. AND F. J. MYERS; Trans. Wis. Acad. Sci. Arts, Letters, vol. 21, 1924, p. 534.

In view of recent research on a number of new species of the genus Monommata, the definition of the mastax will have to be corrected. Only in a few species is the mastax intermediate between the virgate and forcipate types: "rami being lyrate and the inner margins armed with one or more strong teeth immediately below the mouth opening; the unci having three unequally developed, long, slender, clubbed teeth, with the manubra broad and lamellar at the base", as defined by Harring and Myers. In a number of new species there is an extremely simple type of virgate mastax; the rami are lyrate or triangular without inner teeth; the manubra are very simple and rod-like, and the unci have, in most cases, one weakly developed tooth, or are reduced to very thin lamellar, supporting plates. The fulcrum is long and there is a well developed hypopharynx.

MONOMMATA HYALINA Myers, new species

Pl. 23, Figs. 1–3

The body of this species is large, stout and cylindrical, transparent and milky in color; its bulk being greater than that of any other species in the genus. The integument is flexible and the outline varies with the state of contraction of the individual.

The head segment is large, its depth being about equal to its length. The foot is short, stout and obscurely two-jointed. The toes, as usual in this genus, are very long, the left being much shorter than the right; the basal portions are stout and tapering, passing gradually into the cylindrical, slender posterior portions.

The dorsal antenna is situated on a pronounced, setigerous prominence in the normal position; the minute lateral antennae are on the posterior fourth of the body, one on each side.

The corona is oblique and the posterior half is nearly ventral, being prolonged into a very prominent chin-like process. The ciliation consists of a marginal wreath with lateral, auricle-like tufts of longer cilia adapted for propulsion; the apical area

is unciliated and the buccal plate evenly covered with short, close-set cilia.

The mastax is very large and modified virgate in type. The hypopharynx is very prominent, strong and transversely striated. The fulcrum is long, stout and swollen in the middle portion; it is longitudinally striated, the posterior end being recurved and serrate. The rami are roughly triangular, in ventral view, and without a basal apophysis. At the point of articulation on the inner side of the right ramus, there is a denticulate comb-like process having eight or ten teeth. There are no other teeth on the inner margins of the rami. Each uncus has a long, slender, sigmoidal tooth, clubbed at the tip. The basal portions of the manubra are sub-orbicular and plate-like; the posterior portions, rod-like ending with the tips strongly recurved and uncinate. A pair of slender, clavate rods are embedded in the walls of the mastax below the posterior edge of the rami and assist in support during pumping action.

The oesophagus is short. The gastric glands are very small and oval. There is a strong constriction between the clear intestine and the stomach. The ovary and bladder are normal. The foot glands are rather small and pyriform.

The ganglion is large and saccate. The retrocerebral sac is small; the contained bacteroids rendering it more or less opaque to transmitted light. The duct could not be traced beyond the sac, nor could subcerebral glands be found. The eye-spot is large and situated on the posterior end of the ganglion.

Length of the body, 300μ; length of right toe, 350μ; length of left toe, 250μ; length of trophi, 70μ.

Monommata hyalina is fairly common among aquatic plants in permanent bodies of acid water (pH 6.4 — 6.8), on Mt. Desert Island, Maine, and Atlantic County, New Jersey.

MONOMMATA GRANDIS Tessin

Pl. 23, Figs. 4–7

Monommata grandis TESSIN, Arch. Naturg. Mecklenburg, 1890, vol. 43, p. 151, pl. 1, figs. 11, 12.

Monommata grandis LEVANDER, Acta. Soc. Fauna et Flora Fennica, 1895, vol. 12, no. 3, p. 35.

Furcularia longiseta grandis ROUSSELET, Journ. Queckett Micr. Club, 1895, ser. 2, vol. 6, p. 124, pl. 7, fig. 3.

Monommata longiseta grandis STENROOS, Acta. Soc. Fauna et Flora Fennica, 1898, vol. 17, no. 1, p. 135.
Monommata longiseta grandis VOIGT, Forschungsber. Biol. Stat. Plön, 1904, vol. 11, p. 56.
Monommata longiseta grandis SÜSSWASSERFAUNA DEUTSCHLANDS, 1912, pt. 14, p. 104.
Monommata longiseta grandis WEBER AND MONTET, Cat. Invert. Suisse, 1918, pt. 11, p. 119.
Monommata orbis grandis HARRING, Bull. 81, U. S. Nat. Mus., 1913, p. 72.
Monommata grandis HARRING AND MYERS, Trans. Wis. Acad. Sci. Arts, Letters, vol. 21, 1924, p. 538, pl. 43, figs. 6, 7, 8, 9, 10.

The body of this species is elongate and fusiform; the integument is slightly stiffened and the outline is fairly constant in shape. There are two round, red, pigment spots in the position of the lateral antennae that are very characteristic, the function of which is unknown. The foot is obscurely two-jointed and the toes often attain the greatest length development of any species in the genus, although they may sometimes be relatively short. The dorsal antenna is situated on a papillose prominence of medium size and the lateral antennae are in the normal position.

The corona is oblique and the disposition of the cilia is normal to the genus.

The mastax is intermediate between the virgate and forcipate types. The fulcrum is about equal to the rami in length, very broad at the base, tapering to a small, blunt posterior end. The medial portions of the rami are extended laterally into two pairs of very thin lamellae; the basal apophysis is large and separated from the rami proper by a deep sinus; the alulae are large and at right angles to the fulcrum. The inner margins of the rami are equipped with ventral and oral teeth. The ventral group consists of many, twenty-five or more, comb-like denticules on each inner margin; the oral group consists of two pairs, each having four long, slightly curved, opposing teeth joined to strong lamellar plates that have their origin on the ventral sides of the rami. There are no dorsal teeth to the rami. Each uncus has two teeth; the first, or ventral opposing pair, are broad and lemellar, with the truncate tips divided into five small, blunt, tooth-like projections; the dorsal pair are slender and rod-like. The basal portion of the manubra is broad and lamellar; the dorsal cell being rectangular and half

the length of the ventral cell; the median cell is rod-like and decurved near the tip.

The oesophagus is short. The gastric glands are elongate and oblong with their longitudinal axis pointing dorso-ventrally. There is no constriction between the stomach and intestine. The ovary is very long and the bladder is small. The foot glands are small and pyriform. The toes vary in size with the individual, being extremely long in some specimens and not much longer than the body in others.

The ganglion is large and saccate. The retrocerebral sac is small and contains massed bacteroids. The duct is prominent and continues without interruption to the outlets on the face of the corona. There seem to be no subcerebral glands.

There are confluent salivary glands attached to the posterior part of the mastax, each containing several nuclei.

The eyespot is slightly ventral, situated near the posterior tip of the ganglion.

Length of the body, 190 — 240μ; length of right toe, 210 — 400μ; length of left toe, 150 — 300μ; length of trophi, 35μ.

Monommata grandis is common in permanent bodies of water in New Jersey, Wisconsin, Florida and Maine. In fact, it may be considered a cosmopolitan species, being found in both acid and alkaline waters, wherever collections have been made. Its nearest relative is *Monommata maculata,* from which it is easily separated by the differences in the trophi, the extension to the outlets to the face of the corona, of the retrocerebral duct; the presence of confluent salivary glands and the two round, red, areas in the position of the lateral antennae.

As this is evidently the animal described by Tessin, a new name will have to be proposed for *Monommata grandis,* redescribed by Harring and Myers in 1924. Therefore, that species is now renamed *Monommata maculata,* new species, Harring and Myers.

MONOMMATA ENEDRA Myers. new species

Pl. 24, Figs. 1–3

The body of this species is elongate and cylindrical. The integument is slightly stiffened and the shape is fairly constant. The head is separated from the body by a distinct constriction with several marked dorsal skin folds. There is a prominent

tail overhanging the foot and there are several wrinkles at the point where the body and tail meet. The foot is obscurely two-jointed and the toes are normal to the genus.

The corona is oblique and the disposition of the cilia is the same as in the other species of the genus.

The virgate mastax is very small and simple. The fulcrum is somewhat sigmoidal, long, and slender, tapering gradually towards the posterior end. The rami are triangular, in ventral view, without teeth or denticules; the dorsal portion of each forms almost a right angle with the ventral portion and the alulae are prominent and divergent. The manubra are reduced to simple rods; there is a dorsal change of direction in each, forming an obtuse angle, near the posterior end. The bases of the manubra are produced into very fine rods that rest on the rami near the middle. There are a pair of excessively thin lamellar plates connecting the dorsal portion of the rami with the posterior two-thirds of the manubra.

The oesophagus is long and the gastric glands are small and oval in shape. The intestine is clear and slightly constricted at the point of junction with the stomach. The ovary, bladder and foot glands are normal.

The dorsal antenna is a small setigerous tuft and is not papillose as in some of the other species of the genus. The lateral antennae are normal.

The ganglion is large and saccate. There is no apparent retrocerebral sac. The eyespot is large and dark, situated on the posterior end of the ganglion; it has a small globule of high refractive index just in front of the pigment. There are no subcerebral glands.

Length of the body, 150μ; length of right toe, 210μ; length of left toe, 155μ; length of trophi, 25μ.

Monommata enedra is rare, having been found only in the acid waters of Aunt Bettie's Pond, Mt. Desert Island, Maine, and Lenapi Lake, Atlantic County, New Jersey (pH 6.4). It is readily distinguished from the other species of the genus by the absence of a retrocerebral sac; the very small and simple mastax; the refractive globule in front of the eye-pigment, together with the presence of a prominent tail.

MONOMMATA AESCHYNA Myers, new species

Pl. 24, Figs. 4–6

The body of this species is elongate and fusiform. The head is separated from the trunk by a slight constriction accented by several skin folds. The body falls away gradually, from a point above the junction of the stomach with the intestine, to the foot which is long and obscurely three-jointed. The toes are normal to the genus. The dorsal antenna is a setigerous tuft on a slight prominence and the lateral antennae are in the normal position.

The corona is ventrally inclined and has the normal disposition of cilia.

The mastax is virgate, small and simple. The fulcrum is long and straight with the posterior end slightly recurved, and expanded at the tip for the attachment of the muscles. The rami are triangular, in ventral view, without teeth or denticulations; the dorsal portion forms a right angle with the ventral portion. The alulae are prominent and divergent. The basal apophysis is large, acutely triangular, and separated from the rami proper by a deep sinus. The manubra are reduced to simple rods, the basal portions being slightly swollen and the posterior portions strongly recurved. On the middle of the dorsal side of each manubrum is a blunt, tooth-like, process which may be the vestigal remnant of the dorsal cell. There is one slender tooth in each uncus that rests on the rami at the point where the anterior and posterior portions form right angles.

The oesophagus is short and the gastric glands are small and oval. The stomach and intestine are separated by a slight constriction. The ovary, bladder and foot glands are normal.

The ganglion is rather small and saccate. The retrocerebral sac is small, round, and ductless, containing densely clustered bacteroids at the distal end. The eye is situated on the ventral side of the ganglion, just forward of the posterior end.

Length of the body, 150μ; length of right toe, 165μ; length of left toe, 145μ; length of trophi, 25μ.

Monommata aeschyna is rare. It was collected in Cordoy Creek, Atlantic County, N. J. (pH 6.0), and in ice ponds at Mansett, Mt. Desert Island Maine (pH 6.4). In both cases, this species was found in sphagnum from which it was released by squeezing the water out of the moss into a watch glass.

MONOMMATA DIAPHORA Myers, new species

Pl. 24, Figs. 7–9

The body of this species is very long and cylindrical; it has a characteristic swelling just above the anterior portion of the stomach that is constant in all individuals. The foot is stout and obscurely two-jointed and the toes are, as usual, very long and normal to the genus.

The dorsal antenna is a setigerous tuft on a slight prominence and the lateral antennae are in the normal position.

The corona is oblique and the ciliation is normal.

The mastax is virgate. The fulcrum is of moderate length and diminishes gradually from the base to the posterior end. There is no basal apophysis. The rami are triangular, in ventral view, without teeth or denticulations; the dorsal portion forms a right angle with the ventral portion, and the alulae are prominent and divergent. The manubra are reduced to simple rods and are attached to the rami by a pair of extremely thin, lamellar plates, that represent the dorsal cells. On the ventral side of each manubrum, at the point where a dorsal change of direction occurs, there is a spur resembling a tooth. There is one slender sigmoidal tooth in each uncus, resting on each ramus near the middle of the anterior portion.

The oesophagus is short and the gastric glands very small and round. The stomach and intestine are separated by a slight constriction. The bladder is very small and the ovary and foot glands are normal.

The ganglion is large and saccate. The retrocerebral sac is crowded with bacteroids and has a broken duct with outlets on the face of the corona. There are a large pair of confluent salivary glands, with contained nuclei, attached to the posterior portion of the mastax. The eye is on the ventral side of the ganglion near the posterior end and there is a small refractive globule just in front of the red pigment.

Length of the body, 225μ; length of right toe, 260μ; length of left toe, 225μ; length of trophi, 25μ.

Monommata diaphora is fairly common in acid water of the littoral region of ponds and lakes in Atlantic County, N. J. and Mt. Desert Island, Maine, (pH 6.2 — 6.4). Superficially, it resembles *Monommata enedra,* but is easily distinguished from it by the presence of a retrocerebral sac with its broken duct;

the confluent salivary glands; the absence of a prominent tail and the differences in the trophi.

MONOMMATA APPENDICULATA Stenroos

Pl. 25, Figs. 1–4

Monommata appendiculata STENROOS, Acta Soc. Fauna Flora Fennica, vol. 17, no. 1, 1898, p. 135, pl. 1, figs. 33, 34.

The body of this species is stout and cylindrical. The integument is slightly stiffened, finely striated throughout, including the head, making the general shape fairly constant. There is a slight constriction between the head and the abdomen marked by several obscure dorsal skin folds. There is a very prominent tail overhanging the foot, with a well marked constriction at the point where it joins the body. This caudal projection is very characteristic and seems to be of slightly stiffer cuticle than the remainder of the body, as it retains its shape, even in fully contracted individuals.

The foot is indistinctly two-jointed and the toes are normal in shape, although they are relatively shorter in length than in most of the species of the genus.

The dorsal antenna is a setigerous tuft on a slight prominence and the lateral antennae are in the normal positions.

The corona is slightly oblique and the disposition of the cilia is normal to the genus.

The mastax is very minute, for such a large animal, and is of the virgate type. The fulcrum is long and, in lateral view, tapers from the base to the posterior end, which is squarely truncate. The rami are triangular in ventral view; the dorsal portions are gradually bent so that near the tips they are almost at right angles to the ventral portions. The alulae are large and divergent. The basal apophysis is acute and acicular. The unci each have two teeth, appearing as one in lateral view. The anterior pair are slender and rest on the ventral portions of the rami near their base; the posterior pair are very thin and rod-like, resting on the dorsal portions of the rami near the tips. These teeth are actually the bounding edges of the two very thin, lamellar plates, the dorsal edges of which rest on the lateral edges of the rami. The manubra are short and stout, the basal portions, sub-square and lamellar; the posterior portions rod-like and slightly decurved at the ends.

The oesophagus is long. The gastric glands are small and oval. There is a slight constriction between the stomach and the intestine. The bladder is small as are the foot glands. The ovary is normal.

The ganglion is large and saccate. The retrocerebral sac is large, containing a few scattered bacteroids. The retrocerebral duct is rudimentary. The eyespot is large and situated on the posterior end of the ganglion.

Length of the body, 225 — 250μ; length of right toe, 235 — 250μ; length of left toe, 165 — 185μ; length of trophi, 25μ.

Monommata appendiculata was collected in Faun Pond, Witch Hole, Toad Hole and the Barcelona, Mt. Desert Island, Maine; also, from Bargaintown, Atlantic County, N. J., all bodies of permanent acid water with an average pH value of 6.6.

In the Synopsis of the Rotifera, Harring gives *Monommata appendiculata* as a synonym for *Monommata orbis grandis* Tessin, and in the Rotifer Fauna of Wisconsin, Harring and Myers give it as a synonym for *Monommata grandis* Tessin. The figure and description of Stenroos are correct, as far as they go, and the species is a perfectly valid one.

Monommata appendiculata may be recognized at once by its color. The internal organs as well as the integument are always, as far as known, of a yellowish orange tint. This, together with the stiff posterior appendage (so-called tail) and the large, clear retrocerebral sac, together with the minute trophi, are enough to separate it from any other species of the genus.

MONOMMATA ASTIA Myers, new species

Pl. 25, Figs. 5–7

The body of this small species is very long, slender and cylindrical; it is slightly swollen over the lumbar region from where it falls rapidly away to the foot. The integument is slightly stiffened and the body shape is fairly constant.

The head segment is long and narrow and is separated from the abdomen by a well marked constriction. The foot is obscurely two-jointed and the toes are, relatively, the shortest of any species in the genus.

The dorsal antenna is a minute setigerous tuft and the lateral antennae are in the normal position.

The corona is squarely truncate for half its depth, then falls away abruptly to almost prone, giving the whole a snout-like appearance. The ciliation is normal to the genus.

The mastax is virgate and very simple. The fulcrum is a long, slender, sigmoidal rod. The rami are lyrate in ventral view and approximately at right angles to the fulcrum for their entire length. Each uncus is an excessively thin, lamellar plate, the boundaries of which give the impression of very slender linear teeth. The manubra are reduced to a pair of simple rods, each with a slight thickening near the middle of the ventral side. This is a very primitive pumping apparatus and probably the simplest form of the virgate type of mastax.

The oesophagus is short. The gastric glands are very small and oblong oval. There is no constriction between the stomach and the intestine. The ovary, bladder and foot glands are normal to the genus.

The ganglion is long and saccate. The retrocerebral sac is small, black and crowded with bacteroids. The eyespot is small, round and situated at the posterior end of the ganglion.

Length of the body, 120μ; length of right toe, 80μ; length of left toe, 65μ; length of trophi, 15μ.

Monommata astia is common in permanent bodies of acid water; pH range from 6.0 to 7.0. It is the smallest species in the genus, very slow and sluggish in movement. The walls of the stomach are generally crowded with symbiotic zoochlorella and, altogether, the species is so characteristic that it is not easily confused with any other.

MONOMMATA CAECA Myers, new species

Pl. 25, Figs. 8–10

The body of this species is slender and cylindrical. The integument is flexible and the outline varies according to the state of contraction of the individual.

The head segment is relatively short and is separated from the abdomen by several dorsal folds. The abdomen is slightly gibbous dorsally and falls away rapidly from the lumbar region to the foot. The foot is short and obscurely two-jointed. The toes are long and the shape is normal to the genus.

The dorsal antenna is a small setigerous tuft on a slight prominence; the lateral antennae are in the normal position.

The corona is oblique and the ciliation is normal to the genus.

The mastax is virgate. The fulcrum is long and slender, in lateral view, tapering abruptly from the base to the posterior tip. The rami are triangular, in ventral view, and the dorsal portions are bent almost at right angles to the ventral portions. The alulae are divergent, with their bases at right angles to the fulcrum. The unci have two linear teeth which meet at their bases; the ventral pair rest on the rami near the middle; and the dorsal pair rest on the rami near the tips. The area inclosed by the dorsal and ventral teeth of the unci and the lateral edges of the rami are excessively thin lamellar supporting plates. The central cell of each manubrum is shaped like a sigmoidal rod and the basal portion is pyriform. At the posterior end of the dorsal cells of the manubra there are small projecting lobes; the ventral cells are reduced.

The oesophagus is short. The gastric glands are oval and elongate. There is no constriction between the stomach and intestine. The bladder is very small as are also the foot glands. The ovary is normal.

The ganglion is moderately large and saccate. The retrocerebral sac is large, round and clear, while the duct can be traced for some distance forward. There is no eyespot.

Length of the body, 170μ; length of right toe, 210μ; length of left toe, 170μ; length of trophi, 25μ.

Monommata caeca is rare. It was collected at Bargaintown, Atlantic County, N. J. (pH 6.4), and in a creek that is the outlet of a pond situated in a depression on the top of a hill, called The Bowl, Mt. Desert Island, Maine (pH 6.4).

This species cannot be easily confused with any other of the genus, as it is the only one without an eyespot.

MONOMMATA CAUDATA Myers, new species

Pl. 26, Figs. 1–3

The body of this species is elongate and fusiform. The integument is flexible and the shape of the body varies with the state of contraction of the individual.

The head segment is separated from the abdomen by a slight constriction. The posterior part of the abdomen falls away

suddenly to the base of a well marked, bifid caudal projection. The integument is covered with striations that curve dorsally and meet above the tail. The foot is obscurely three-jointed and the toes are normal to the genus.

The dorsal antenna is situated well forward, the small setigerous tuft projects from a minute prominence; the lateral antennae are in the normal position.

The corona is oblique and the disposition of the ciliation is normal to the genus.

The mastax is virgate. In lateral view, the fulcrum tapers suddenly from a wide base to a long, rod-like, posterior portion. The rami are lyrate, in ventral view, and have two obtuse, angular projections on the inner sides at the point where the ventral teeth of the unci rest. The basal apophysis is long, acute and acicular. The unci each have one apparent linear tooth; they are, in reality, the ventral boundaries of thin lamellar plates resting on the lateral edges of the rami and acting as supports during pumping action. The dorsal boundaries of these plates are marked by linear strengthening rods connecting the dorsal cells of the manubra with the tips of the rami. The manubra are sub-square and lamellar, ending in slightly recurved portions. Near the middle of the central cells of each is a decurved lobe-like projection.

The oesophagus is short. The gastric glands are round and minute. There is no constriction between the stomach and the intestine. The bladder, as is usually the case in the genus, is small. The ovary and foot glands are normal.

The ganglion is moderately large and saccate. The retrocerebral sac is small and black with densely packed bacteroids. The eye is small and situated at the posterior end of the ganglion.

Length of the body, 180μ; length of right toe, 210μ; length of left toe, 180μ; length of trophi, 22μ.

Monommata caudata is rare, the only location where it has been found being Aunt Bettie's Pond, Mt. Desert Island, Maine (pH 6.2). As it is the only species in the genus with a bifid tail and the characteristic longitudinal striations, all meeting on the dorsal side, it can hardly be confused with any other.

MONOMMATA ACTICES Myers, new species

Pl. 26, Figs. 4–7

The body of this species is slender and cylindrical, falling away gradually from the neck to the foot. The head segment is long and set off from the abdomen by several strong, dorsal projections and skin folds. The integument is covered with faint longitudinal striations, as are most of the other species of the genus, omitted in the figures for the sake of clarity unless very strongly marked. There are a pair of large, round, areas in the position of the lateral antennae, one on each side of the abdomen; they may be either deep red or clear. If clear, and their presence is unsuspected, they may be made visible as yellowish spots by intravitam staining with brunswick brown. The foot is obscurely two-jointed and the toes are normal to the genus.

The dorsal antenna is situated on a papillose prominence and is in the form of a small tubule from which emerges a setigerous tuft of cilia. It is interesting to note that the tubule may be entirely retracted within the integument of the head and its presence unsuspected. The lateral antennae are in the position of the lumbar spots.

The corona is oblique and the ciliation is normal to the genus.

The mastax is minute, virgate and very simple. The fulcrum is long and rod-like, gradually decreasing in lateral view, from the base for about one-third its length. The rami are very slender and lyrate, in ventral view. The alulae are rod-like and divergent. The rami are bent abruptly downward near the middle to an angle of about one hundred degrees. The unci each have two short linear teeth; the ventral pair rest on the rami near the posterior parts of the dorsal portions; the dorsal pair rest on the rami near the middle of the dorsal portions. There are a pair of thin, lamellar supporting plates bounded by the dorsal teeth of the unci and very fine, linear strengthening rods connecting the tips of the rami with the dorsal sides of the manubra.

The oesophagus is short. The gastric glands are moderately large and round. There is no constriction between the stomach and the intestine. The foot glands and bladder are small and the ovary is normal.

The ganglion is large and saccate. The retrocerebral sac is

small and contains numerous bacteroids clustered on the ventral side. There are remnants of a retrocerebral duct that can be traced to the outlets on the corona by intravitam staining with brilliant cresylblau, or brunswick brown. (When there is any doubt about the presence of a retrocerebral sac and ducts, all rotifers should be subjected to intravitam staining, as these organs are often invisible without it). There is a suggestion of confluent salivary glands and the eyespot is at the posterior end of the ganglion.

Length of the body, 195μ; length of right toe, 210μ; length of left toe, 150μ; length of trophi, 22μ.

Monommata actices is not uncommon in permanent bodies of acid water in Atlantic County, N. J. and on Mt. Desert Island, Maine (pH 6.4 — 6.8). The presence of the revertile, tubular, dorsal antenna, situated on a prominent papilla, and the red, or clear, lumbar areas, together with the fact that the stomach is generally crowded with green symbiotic zoochlorella, enable this species to be easily determined when seen.

MONOMMATA PHOXA Myers, new species

Pl. 26, Figs. 8–10

The body of this species is long and cylindrical; its shape varies with the state of contraction of the individual, as the integument is quite flexible.

The head segment is moderately long and separated from the abdomen by a slight constriction with several dorsal skin folds. The foot is obscurely two-jointed and the toes are normal to the genus.

The dorsal antenna is a minute, setigerous tuft, emerging from a small prominence; the lateral antennae are in the usual position and normal to the genus.

The corona is oblique and the ciliation is normal.

The mastax is virgate. The fulcrum is very long, expanded and serrate at the posterior end for the attachment of the hypopharynx. The rami are bent at nearly right angles near the middle and are lyrate, in ventral view. The alulae are large, triangular, and at right angles to the fulcrum. Each uncus has a cluster of five or six linear teeth arising from a common base and resting on the ventral portions of the rami near their points of junction with the fulcrum. There are a pair of linear rods running from the tips of the rami, appearing to be con-

tinuations of the bases of the two clusters of teeth referred to above. These rods mark the limits of two very thin, lamellar, supporting plates that rest on the lateral sides of the rami. The basal portions of the manubra are rectangular; the dorsal cells are large and each has a decurved lobe-like projection at the posterior angle. The posterior ends of the middle cells are expanded and slightly decurved. There are no ventral cells.

The oesophagus is short. The gastric glands are very small and round. There is a well marked constriction between the stomach and the intestine. The bladder and foot glands are small and the ovary is normal.

The ganglion is small and saccate. The retrocerebral sac is small and contains clustered bacteroids; the duct may be traced for some distance forward. The eye is small and situated on the ventral side of the ganglion near the posterior end.

Length of the body, 150μ; length of right toe, 190μ; length of left toe, 140μ; length of trophi, 35μ.

Monommata phoxa is evidently rare. It was collected in an acid pond (pH 4.4) near English Creek, Atlantic County, N. J. The characters are rather negative and the trophi should be examined in order to determine the species.

For the benefit of those interested in what has been done with the rotifers, this occasion is taken to add the following abstracts and comments, quoting freely from the various authorities.

AFFINITIES

There are very few groups in the animal kingdom with which the rotifers have not at some time or other been supposed to be related, and it is hardly worth while to go into the views of the pioneers on this subject. Ehrenberg was the first to separate the rotifers definitely from the Protozoa; what was left of the old confusion fell to the ground on the advent of the cell-theory. However, it has been proposed that the rotifers and the Gastrotricha may help us bridge the gap between the Protozoa and the Metazoa by the simplicity of their organization and the syncytial character of their tissue, admitting that most of the special characteristics of the rotifers are regressive rather than primitive, in view of their evident relationships with other groups of specialized worms. It is not probable that a large

group of highly specialized organisms can be derived from a lower group, already specialized in quite a different direction, and we cannot derive the Metazoa from the higher Infusoria, as the multiplication of the nuclei and the differentiation were contemporaneous.

Arthropod relationships have been postulated for the rotifers repeatedly by homologizing the hard pieces of the mastax with the oral armature of the insects and in the existence of a post-anal segment in the early development of the blastopore. Hudson attempted to discover affinities between Pedalion and the nauplius-larva. The morphological significance of Pedalion has been much exaggerated; its appendages are not articulated and two of them are unpaired, fundamentally different from the Arthropoda. It is true that this is not absolute proof, because the ancestral forms, before acquiring metameric and articulated appendages, must have had something simpler; the real reason is that the rotifers and especially Pedalion, are too highly specialized to have become the ancestors of another large group, which would have had to lose the special characteristics and acquire others in their place. Affinities with the Nematoda through Gastrotricha-Kinorhyncha-Chaetognatha are hardly less problematic.

Coming now to the problem of postulating affinities between rotifers and various metazoan larvae, which has been examined and usually adopted by most authors who have studied this problem, the theory which makes the rotifer equivalent to the trochophore of the Annelida and related groups suffers from a serious fundamental objection. How far is it legitimate to compare a larva with an adult; how far is the parallelism of ontogeny and phylogeny supported by facts sufficient to sustain such an hypothesis? There are two questions involved in the trochophore theory as it is usually presented. First: Does the trochophore of to-day actually repeat the forms of an annelid ancestor? Second: Is the rotifer really comparable to the trochophore? Affirming the first will involve the colonial theory of metemerism, but regardless of accepting or rejecting this, it would be possible to affirm the second. According to the first statement the rotifer must be a direct descendant of the trochophore ancestor of the Nephridiates, if not in truth the real ancestor itself. In the second case it is simply an annelid larva which by neoteny must have acquired genital

glands and become an independent organism. In order to decide, we will have to review the organization of the rotifers and compare it with the trochophore and the adult forms of related groups.

First, we must dispose of a point of some importance in this comparison: Is the adult annelid simply a trochophore which has become elongated and segmented, or is it a different animal formed by budding from the trochophore, something like a medusa. The pluteus-larva does not metamorphose into a sea-urchin or the trochophore into an annelid; in these cases one individual only is present, forming transitory organs, absorbing them again and developing others, and we find all the intermediates between this metagenetic and the perfectly straight development, if such really exists.

A comparison of the general form of rotifers and the trochophore is without interest as it is extremely variable in both groups. And we must realize that no significance whatever is to be attached to the famous genus Trochosphaera, usually considered as proving the above theory: its spherical form is just as rare among annelids as among rotifers, and is simply a secondary adaptation like everything else in its organization. As to the discussion of homologies of the different organs of the annelids, rotifers and the trochophore, they must be considered without any foundation in reality. Only one point is worthy of notice: the presence of a post-anal section adapted to fixation, the so-called foot, in nearly all rotifers. It is not difficult to follow its gradual development, but nevertheless it is an important difference between rotifers and trochophores, because it is quite evident that the few genera without foot have lost it by adaptation to special conditions, especially to a pelagic life.

There is another question of much greater importance; that of the coelome, and also of the nephridia, which is bound up with it. We know that in the Platodes the space between the ectoderm and endoderm is filled with parenchyma, derived mainly from the ectoderm, and from which the muscular fibres are differentiated. In the trochophore we find a similar parenchyma distributed in what remains of the segmentation cavity, the blastocoele, and from this the larval muscles originate. But in the adult the coelomic sacs, formed from the mesoderm, which have furnished the endoderm near the lower extremity,

invade the blastocoele, push back the primitive mesenchyme and form the coelomic cavity, lined with epithelium, its walls furnishing the muscalature of the body and digestive tube. In the molluscs this parenchyma furnishes only the pericardium, the kidneys and the glands. This ectomesoblast and coelomesoblast are quite distinct, as they succeed each other in the same animal.

If we now apply this to rotifers, we find a vast body cavity, which might be taken for a coelome; it is, however, without trace of epithelium and contains as mesoderm only a few scattered cells of unknown origin, and the muscles, which originate from the ectoderm; it is thus an ectomesoblast, comparable with the parenchyma of the Turbellaria, from which it differs only in its tenuity, leaving the blastocoele cavity all but empty. But the ovary of the rotifers is derived from the endoderm, and they are therefore in the ectomesoblastic stage of the Platodes, more primitive than the molluscs or the adult annelid.

The nervous system of the rotifers is insufficiently known to be of any use in this comparison. The supposed suboesophageal ganglion is in no sense an independent nerve center, but a few cells imbedded in the walls of the mastax; it is not even certain that they are nerve cells, but it may be a mastax ganglion and certainly has nothing to do with the suboesophageal ganglion of the Annelida.

More important, because absolutely limited to the rotifers and the Gastrotricha are the sensory tentacles, typically in two pairs, but reduced to three among the majority of the rotifers by fusion of the upper pair. They are never present in the trochophore and are obviously the product of a long course of evolution.

In the digestive tract the only important organ in our review is the mastax. Although this is evidently homologous with the stomodeal formations in related groups, maxillary bulb and radula, it cannot be derived from either or vice versa; their origin must be sought in the triradiate pharynx of the Turbellaria.

The ciliation must be admitted as of importance in the study of the phylogeny of the rotifers. It is the only argument for a relationship between the rotifers and the trochophore. But a study of the animals shows the greatest variation in both groups, and also that the rotifers and the larval forms men-

tioned are the only Artiozoa moving by swimming with the aid of vibratile cilia and if external causes react upon the ciliation, it is not surprising that the same causes should have produced similar effects on unrelated animals and that, starting from uniformly ciliated ancestors, the various trochophores as well as the various rotifers have developed without ever having had any common ancestor possessing their general characters.

Many of the characters reviewed are common to the rotifers and the trochophore. But all that are larval characteristics (mesenchyme and nephridial) in the annelids and molluscs and on which the homologisation has been founded, are adult characteristics among the Platodes and the Turbellaria, for instance, and there is no reason whatever in favor of any one relationship rather than some other. We have considered the only remaining characteristic, the ciliation, which is not found in adult animals other than the rotifers and the Gastrotricha. If the colonial theory is ruled out, there remains only the neoteny hypothesis: possible, but absolutely unproven and unprovable. There is nothing to show that the ancestors of the rotifers ever were metameric or possessed a coelome, and there is no indication that any group in the animal kingdom originated in this way.

Many views have been advanced as to the affinities of the rotifers, especially as regards their relationships to higher forms; these opinions will not, however, be fully considered here, but merely indicated, attention being directed first to the relationships in which rotifers stand to organisms lower in the scale. In this connection the excretory system becomes of no little importance on account of its resemblance to that of the Turbellaria, a resemblance which is further emphasized by the nervous system, consisting of a simple brain from which the posteriorly-directed nerve-cords arise; by the combined ovary and vitellarium, and by the absence of a blood vascular system. Here, however, the resemblance ceases, and the presence of an anal opening to the digestive tube marks the rotifers as standing on a higher level than the Turbellaria. It seems probable, however, that the similarities do indicate the ancestry, and that the Rotifera have been derived from the Turbellarian type.

Another possibility which has been suggested is to the effect that they are derived from the trochophore larvae of the Annelida. The principal argument for this view is found in the

arrangement of the trochal cilia, which, in the occurrence in many cases of both preoral and postoral bands, certainly resembles not a little that of the trochophore larva. It must be remembered, however, that the similarity in the arrangement of the cilia is not quite perfect, and that it may be without phylogenetic significance, having been acquired independently in the rotifers and in the trochophore larva; and furthermore, it is noticeable that in one important character at least, a marked difference is found, the nervous ganglion lying in the rotifers behind instead of before the preoral band of cilia. The most that can be said at the present is that the rotifers show closer structural affinities to the Turbellaria than to any other group, and that it is probable that they represent the culmination of a line of development originating in that group; and furthermore, that it is possible that they represent the ancestral annelid form indicated by the trochophore larva.

In contradistinction to almost all other great divisions of the animal kingdom which are bound to fresh water, the fresh water seems to be the real home of the rotifers, the element in which the group originated. What characterizes the fresh water fauna is that it is an emigrant fauna, either derived from the sea or from the land; a fauna of emigrants, the home of which was originally to be found everywhere, not only in the element in which it now lives: the fresh water itself. Owing to the peculiar conservatory power of the fresh water with regard to all types of animals which, from the oldest epochs of the earth to our own day, escape into it, the fresh water fauna is a relict fauna, to which the oldest prehistoric oceans as well as our present ones have provided and still provide their contingents. We are not for a moment in doubt that the developmental centers of the Bryozoa, Sponges, Crustacea, Coelenterates, Insects, Molluscs and Fishes have never lain in the fresh water; what occurs of these great divisions in the fresh water is only to be regarded as remnants, separated from the main stock, often in the dawn of the earth. As far as we have been able to see, the Rotifera is the only division of fresh-water organisms which can not be regarded from this point of view. It seems as if their developmental center has really been in the fresh waters; they are almost lacking in the sea, and apart from the very aberrant Seisonacea, they never develop special forms there. That the land rotifers, the moss

fauna of the trees and rocks, are derived from fresh water, needs no further explanation. Owing to this view, which is permissible, especially with regard to animals about whose phylogeny paleontology gives no answer at all, we are disinclined to see near relationship with marine animals.

This view is further strengthened by the following fact. If we survey the other fresh-water organisms of marine derivation, it is easy to show that the members of these different phyla, the Sponges, the Bryozoa, the Coelenterates, the Crustacea and the Fishes, are a remarkably casual medley of organisms, whose affinities are often much nearer to marine organisms than to fresh water organisms of the same phyla, with which they live side by side. At the present time they frequently show no affinities at all with organisms from the present geological epoch, whereas their affinities with extinct marine animals are to be regarded as established facts. However different the rotifers may be, this view does not apply; the very fact that so many of the families may be arranged in developmental lines with their extreme stages finishing as plankton organisms and their origin traced back to creeping organisms, gives support to the idea that they have a common source.

That all these developmental lines actually did originate in fresh water and not in the sea, is in our opinion obvious, because they have, during their development, adapted themselves biologically to the rules which many other fresh-water organisms have been forced to follow, if this element was to be their home; one thinks especially of the reproduction, the heterogony, the importance of the resting eggs in the life history of the rotifers, all phenomena which the rotifers share with so many other fresh water organisms and which occur but rarely or not at all in the marine forms.

If this supposition of the fresh water as the original home of the rotifers is correct, and if it is also true that the creeping, slowly swimming bottom and littoral forms are the most primitive, then the Turbellaria appear to be the freshwater group to which the rotifers are most closely related. This view is based especially upon the structure of the excretory organs, alike in both groups, and the corona. It is at all events not weakened by a consideration of the biology of the animals, especially the reproduction of the fresh water Turbellaria, where we find the same phenomena governing the rotifers, such as heterogony,

parthenogenesis, resting eggs and the absence of the larval stage.

The great majority of the rotifers live in fresh water, a much smaller number lives in brackish water and the smallest number of all is purely marine.

EMBRYOLOGY

The development of the rotifers is very imperfectly known. Early attempts to elucidate the subject failed, largely on account of the imperfections of available technique and the conclusions drawn were misleading. All authors agree that the parthenogenetic egg passed through only a single maturation division, without any reduction of the chromosome number and with the formation of a single polar body.

The development of *Asplanchna ebbesbornii* has been studied, as has also that of *Asplanchna priodonta,* which throws some light on the subject. It seems that there is no trace of gastrulation, epibolic or any other kind. What has been universally interpreted as endoderm is simply the germ-cells of the genital organs, which eventually wander into the interior. The blastoderm is at a very early age divisible into definite germinal areas or cell-complexes, which gradually develop into the various organs of the body. If any proof of the absence of gastrulation were needed, it is furnished by the development of the stomach. This begins on the dorsal side, and when the ventral cell layer of the stomach is fully formed, the dorsal wall is still a part of the blastoderm on the dorsal surface, without any covering cell layer or integument.

The embryology of the rotifers is thus a very simple and primitive process, with each organ developing from a definite cell complex of the blastoderm. Cell divisions proceed rapidly until all organs possess their full component of cells; then it ends, definitely and forever; the body of each rotifer has a constant number of cells. It is constant for the same species; whether all rotifers have the same number of cells, regardless of species, is unknown. Nine hundred and eighty-six have been counted in *Hydatina senta* and an estimate of 900 for *Asplanchna priodonta.* This cell-constancy must not be supposed to bring in its train any form-rigidity; Stephanoceros, for instance, is able to regenerate the arms of the corona, even all

five at a time, if necessary, and thus does not show any greater rigidity than other organisms without cell-constancy. The free-swimming young of *Apsilus vorax* has exactly the same number of cells in the same place as the fixed adult animal; the "metamorphosis" is only an instance of cell differentiation.

ROTIFERA-GASTROTRICHA

The majority of textbooks in use today still refer the rotifers to the phylum Trochelminthes, which is supposed to include the rotifers, Gastrotricha, Kinorhyncha, Archiannelida, Histriobdellia and Dinophilus. No one familiar with any of these groups now considers them closely related and there is no justification for maintaining this phylum any longer. The consensus of opinion among students of the rotifers is that they are closely related to the Turbellaria. A vast amount of information has been brought forward on the Gastrotricha in the last few years and some 30 marine species have been discovered where previously only three were known. The fresh water Gastrotricha are so much alike and so simple in their morphology that they do not give any clue to their relationship; the marine order Macrodasyoidea, on the other hand, are much more complex and also much more varied, and it is quite evident that they are closely related to the Nematoda; the fresh water order Chaetonotoidea is shown to be a highly specialized, and in many respects a somewhat degenerate group. The Gastrotricha are also related to the Arachiannelida and thus, distantly through this group to the Annelida.

OOGENESIS

In all rotifers with distinct sexes, two kinds of eggs are formed by distinct categories of females. One kind of egg is absolutely parthenogenetic and always produces a female. The other kind is faculatively or incidentally parthenogenetic; if this egg remains unfertilized it develops into a male, if fertilized it becomes a resting egg, which eventually develops into a female.

The faculatively parthenogenetic egg possesses a normal oögenesis, similar to all normal metazoan eggs; a synaptic pro-

phase is formed very early; there is a pseudoreduction of the chromosome number, followed by normal maturation divisions. The haploid chromosome number is 8 in *Asplanchna priodonta.* This egg is fertilizable in its early development; if fertilized it develops into a large, thick-shelled resting egg. The nuclear changes and maturation divisions do not differ materially from the unfertilized male egg.

The oögenesis of the absolutely parthenogenetic egg is atypical. The nucleus remains inactive until shortly before the maturation division, when it moves to the periphery of the egg, passes rapidly through a somatic prophase; this is followed by a single maturation division, which is a somatic mitosis. The egg thus remains diploid and is notable for the loss of the reduction division and the total absence of a synaptic prophase, which is an absolutely necessary preliminary to a reduction division.

The sexual process is a succession of nuclear changes, passing from diploidy through haploidy and again to diploidy, a regular sequence through synaptic prophase, reduction divisions and nuclear coalescence. This process we will call mixis, without limiting it by minor details or including any theories of inheritance. With this definition the normal egg-cells and spermatozoa are mictic cells, and the faculative parthenogenetic eggs of rotifers are faculatively mictic cells. The absolutely parthenogenetic rotifer egg is characterized by being unfertilizable, the loss of the reduction division and the synaptic prophase.

This form of the sexual process may be called amixis and the resulting eggs are thus amictic. Probably all metazoan parthenogenetic, diploid eggs belong here. As these eggs are developed in different animals in the species of Asplanchna, it is better to call these mictic and amictic females rather than male-producing or female-producing females, sexual females, etc.

The single nuclear spindle of the amictic egg is atypic in form. The achromatic figure is a semi-ellipse or truncate cone, with its base on the egg membrane. The centrosome appears in the center of the egg-plasma, away from the nucleus, at the beginning of the prophase; it is evident that this does not pass through any division. This unusual behavior of the centrosome is probably accounted for by the nature of the amictic

egg. In it the maturation division has become a meaningless rudimentary process, but the centrosome has acquired a new function; in the mictic egg the centrosome disappears; in the amictic egg the centrosome passes to the new generation, becoming active in the first segmentation division.

DESICCATION

The ability of certain rotifers, tardigrades and nematodes to withstand periods of desiccation has been known for over two hundred years.

Various explanations and theories have been advanced from time to time since then attempting to explain the phenomenon and the question intermittently discussed without adding anything substantial to what was already known. Not until Dr. Hickernell, then a graduate student at Princeton University, took up the work in 1914, was any real light shed on the puzzle. He attacked it from a cytological standpoint and obtained remarkable results. In the living animal the nucleus of the individual cell shows a central, densely stained karyosome surrounded by a clear space, and around this a fairly thin nuclear membrane. The nucleus of the dried animal virtually loses its affinity for stains; the karyosome disappears and what remains of the chromatin has collected on the nuclear wall. These changes are most easily seen in the large cells of the ovary, but are found in all the cells of the body. When the dried rotifer is again moistened, the exact reverse of this phenomenon takes place; the chromatin gradually leaves the nuclear wall and gathers in the center. The purpose of all this is to keep the chromatin in the position where it will most effectively carry out the breaking-down of complex food materials in the cytoplasm, with consequent release of the metabolic water during the process. Thus the dried rotifer is able to use its stored up food reserves at an exceedingly slow rate, so slow that animals have been kept for twenty-seven years in the dried state and revived upon moistening.

It thus seems that the desiccation problem is solved and the solution is as beautiful as it is simple.

DURATION OF LIFE

Actual information on the attainable age of the rotifers is obviously limited to laboratory conditions and this again is dependent on the skill of the experimenter in approaching natural conditions, especially in providing the proper food. The sessile rotifers and the Bdelloids apparently live much longer than the free swimming Ploima. Thus Mr. Bryce maintained several specimens of *Macrotrachela multispinosa* alive 4 months from the date the moss containing them was mailed from Washington, and Cori kept *Cupelophagus vorax* in the laboratory for 6 weeks. Spemann finds for *Rotaria rotatoria* a maximum of 11 weeks and an average of 5 weeks. On the other hand, the "laboratory rotifer", *Epiphanes senta,* belonging to the Ploima, lives on an average of about 2 weeks; Miss Noyes obtained for *Proales decipiens* an average of 6 to 7 days, and Lehmensick 3 weeks for *Euchlanis triquetra.* As to how long the animals would live under natural conditions would be useless to guess; we do not know whether any rotifer ever lived long enough to die of old age; the probability is that the vast majority, if not all, meet an untimely death, as they serve as food for nearly all small aquatic animals.

No considerable contribution to the morphology of the rotifers has been made in the last twenty years.

The most important result of the anatomical investigations is the demonstration of cell-constancy for *Epiphanes senta* by Martini and for *Asplanchna priodonta* by Nachtwey who has studied also the embryology of the species. He found there is no gastrulation; what has been interpreted as such is the invagination of the largest cell of quadrant D in the 4-cell stage, the only macromere in the embryo, which is the origin of the entire genital system. Mastax and oesophagus are developed from an antero-ventral invagination, the balance of the digestive tract from a dorsal invagination. It is evident that the rotifer development stands alone and that it is incorrect to speak of either endoderm or mesoderm.

The cytology of reproduction has been studied by Storch and Tauson. There are only two kinds of female rotifers, fertilizable and non-fertilizable; for the first, as stated previously, Storch has proposed the name mictic, for the second, amictic.

Sex determination has been studied by Luntz and is shown to be dependent on a change of diet.

Seasonal and local variations have been studied by many authors and explained in almost as many ways. At times directly opposite conclusions have been drawn from studies of the same animal. It has never been established that the same line may develop the extreme forms generally considered as belonging to a single species; in the least doubtful cases the line may contain, 2, at times 3, forms "of repose" passing more or less readily from one to another, without necessarily passing through intermediate stages; a change of diet is certainly to be reckoned among the causative factors of this transformation; the adaptive nature of variation in rotifers has not been demonstrated.

Evidently the rotifers are an isolated group, even more so than was formerly supposed.

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Explanation of Plates

PLATE 10

Fig. 1. *Euchlanis dilatata,* acid water form with long lorica, dorsal.
Fig. 2. *Euchlanis dilatata,* acid water form with long lorica, ventral.
Fig. 3. *Euchlanis dilatata,* acid water form with long lorica, lateral.

PLATE 11

Fig. 1. *Euchlanis dilatata,* normal form, lateral.
Fig. 2. *Euchlanis dilatata,* lorica, ventral.
Fig. 3. *Euchlanis dilatata,* lorica, rear.
Fig. 4. *Euchlanis dilatata,* form with deep dorsal plate, rear.
Fig. 5. *Euchlanis dilatata,* lorica, lateral.
Fig. 6. *Euchlanis dilatata,* lorica, cross-section.
Fig. 7. *Euchlanis dilatata,* lorica, triradiate form, rear.
Fig. 8. *Euchlanis dilatata,* trophi, frontal.

PLATE 12

Fig. 1. *Euchlanis parva,* lateral.
Fig. 2. *Euchlanis parva,* lorica, ventral.
Fig. 3. *Euchlanis parva,* cross-section.
Fig. 4. *Euchlanis parva,* trophi, frontal.
Fig. 5. *Euchlanis parva,* posterior notch.
Fig. 6. *Euchlanis parva,* section at A, fig. 5.
Fig. 7. *Euchlanis oropha,* lorica, ventral.
Fig. 8. *Euchlanis oropha,* lorica, cross-section.
Fig. 9. *Euchlanis oropha,* trophi, frontal.
Fig. 10. *Euchlanis oropha,* toe, lateral.
Fig. 11. *Euchlanis, lateral* antenna.

PLATE 13

Fig. 1. *Euchlanis triquetra,* lateral.
Fig. 2. *Euchlanis triquetra,* lorica, ventral.
Fig. 3. *Euchlanis triquetra,* lorica, rear.
Fig. 4. *Euchlanis triquetra,* lorica, cross-section.
Fig. 5. *Euchlanis triquetra,* trophi, frontal.

PLATE 14

Fig. 1. *Euchlanis phryne,* dorsal.
Fig. 2. *Euchlanis pellucida,* lorica, dorsal.
Fig. 3. *Euchlanis pellucida,* lorica, cross-section.
Fig. 4. *Euchlanis pellucida,* variety, lorica, cross-section.
Fig. 5. *Euchlanis pellucida,* trophi, frontal.
Fig. 6. *Euchlanis pellucida,* toes, dorsal.

PLATE 15

Fig. 1. *Euchlanis phryne*, lorica, ventral.
Fig. 2. *Euchlanis phryne*, lorica, cross-section.
Fig. 3. *Euchlanis phryne*, trophi, frontal.
Fig. 4. *Euchlanis phryne*, trophi, lateral.
Fig. 5. *Dapidia pyriformis*, lorica, ventral.
Fig. 6. *Dapidia pyriformis*, lorica, front.
Fig. 7. *Dapidia pyriformis*, trophi, frontal.

PLATE 16

Fig. 1. *Euchlanis alata*, dorsal.
Fig. 2. *Euchlanis alata*, lorica, ventral.
Fig. 3. *Euchlanis alata*, lorica, form without "wings".
Fig. 4. *Euchlanis alata*, lorica, cross-section. Specimen from Maine.
Fig. 5. *Euchlanis alata*, lorica, cross-section. Specimen from New Jersey.

PLATE 17

Fig. 1. *Euchlanis alata*, lorica, lateral oblique, "winged" form.
Fig. 2. *Euchlanis alata*, lorica, posterior oblique, "winged" form.
Fig. 3. *Euchlanis alata*, trophi, frontal.
Fig. 4. *Euchlanis alata*, trophi, lateral.
Fig. 5. *Euchlanis alata*, toe, lateral.
Fig. 6. *Euchlanis callysta*, lateral.
Fig. 7. *Euchlanis callysta*, lorica, ventral.
Fig. 8. *Euchlanis callysta*, trophi, frontal.
Fig. 9. *Euchlanis callysta*, lorica, cross-section.

PLATE 18

Fig. 1. *Euchlanis lyra*, lateral.
Fig. 2. *Euchlanis lyra*, lorica, ventral. Specimen from Epping Forest, England.
Fig. 3. *Euchlanis lyra*, lorica, ventral. Specimen from Donaveshingen, Baden.
Fig. 4. *Euchlanis lyra*, lorica, cross-section.
Fig. 5. *Euchlanis lyra*, trophi, frontal.

PLATE 19

Fig. 1. *Euchlanis proxima*, lateral.
Fig. 2. *Euchlanis proxima*, lorica, ventral.
Fig. 3. *Euchlanis proxima*, trophi, frontal.
Fig. 4. *Euchlanis proxima*, lorica, cross-section.
Fig. 5. *Euchlanis meneta*, lateral.
Fig. 6. *Euchlanis meneta*, lorica, dorsal.
Fig. 7. *Euchlanis meneta*, cross-section, normal form; dotted line, triradiate form.
Fig. 8. *Euchlanis meneta*, trophi, frontal.

PLATE 20

Fig. 1. *Dapidia calpidia,* dorsal.
Fig. 2. *Dapidia calpidia,* lorica, cross section.
Fig. 3. *Dapidia calpidia,* lorica, cross-section, triradiate form.
Fig. 4. *Dapidia calpidia,* lorica, cross-section, deep dorsal plate.
Fig. 5. *Dapidia calpidia,* trophi, frontal.
Fig. 6. *Dapidia calpidia,* trophi, lateral.
Fig. 7. *Dapidia calpidia,* lorica, ventral. Specimen from Starvation Lake, Wisconsin.
Fig. 8. *Dapidia calpidia,* lorica, cross-section. Specimen from Starvation Lake, Wisconsin.

PLATE 21

Fig. 1. *Dapidia deflexa,* dorsal.
Fig. 2. *Dapidia deflexa,* lorica, ventral.
Fig. 3. *Dapidia deflexa,* lorica, cross-section.
Fig. 4. *Dapidia deflexa,* toe, lateral.
Fig. 5. *Dapidia deflexa,* trophi, frontal.

PLATE 22

Fig. 1. *Tripleuchlanis plicata,* dorsal.
Fig. 2. *Tripleuchlanis plicata,* lateral.
Fig. 3. *Tripleuchlanis plicata,* lorica, cross-section.
Fig. 4. *Tripleuchlanis plicata,* trophi, dorsal.
Fig. 5. *Dipeuchlanis propatula,* lorica, dorsal.
Fig. 6. *Dipeuchlanis propatula,* lorica, cross-section.
Fig. 7. *Dipeuchlanis propatula,* trophi, frontal.

PLATE 23

Fig. 1. *Monommata hyalina,* lateral.
Fig. 2. *Monommata hyalina,* trophi, oblique frontal.
Fig. 3. *Monommata hyalina,* trophi, lateral.
Fig. 4. *Monommata grandis,* lateral.
Fig. 5. *Monommata grandis,* trophi, oblique frontal.
Fig. 6. *Monommata grandis,* trophi, lateral.
Fig. 7. *Monommata grandis,* trophi, dorsal.

PLATE 24

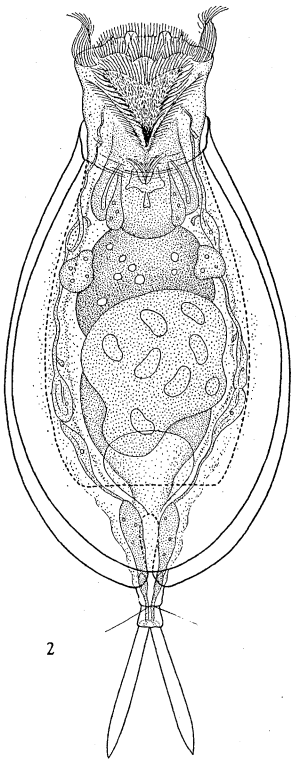
Fig. 1. *Monommata enedra,* lateral.
Fig. 2. *Monommata enedra,* trophi, oblique frontal.
Fig. 3. *Monommata enedra,* trophi, lateral.
Fig. 4. *Monommata aeschyna,* lateral.
Fig. 5. *Monommata aeschyna,* trophi, ventral.
Fig. 6. *Monommata aeschyna,* trophi, lateral.
Fig. 7. *Monommata diaphora,* lateral.
Fig. 8. *Monommata diaphora,* trophi, lateral.
Fig. 9. *Monommata diaphora,* trophi, ventral.

PLATE 25

Fig. 1. *Monommata appendiculata,* lateral.
Fig. 2. *Monommata appendiculata,* trophi, ventral.
Fig. 3. *Monommata appendiculata,* trophi, lateral.
Fig. 4. *Monommata appendiculata,* posterior end body, dorsal.
Fig. 5. *Monommata astia,* lateral.
Fig. 6. *Monommata astia,* trophi, frontal.
Fig. 7. *Monommata astia.* trophi, lateral.
Fig. 8. *Monommata caeca,* lateral.
Fig. 9. *Monommata caeca,* trophi, lateral.
Fig. 10. *Monommata caeca,* trophi, ventral.

PLATE 26

Fig. 1. *Monommata caudata,* lateral.
Fig. 2. *Monommata caudata,* trophi, frontal oblique.
Fig. 3. *Monommata caeca,* trophi, lateral.
Fig. 4. *Monommata actices,* lateral.
Fig. 5. *Monommata actices,* trophi, ventral.
Fig. 6. *Monommata actices,* trophi, lateral.
Fig. 7. *Monommata actices,* dorsal antenna.
Fig. 8. *Monommata phoxa,* lateral.
Fig. 9. *Monommata phoxa,* trophi, ventral.
Fig. 10. *Monommata phoxa,* trophi, lateral.



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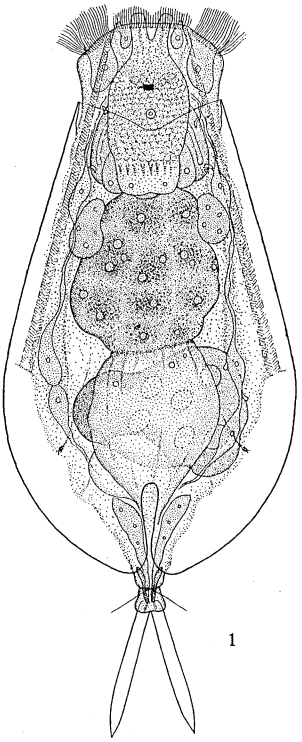

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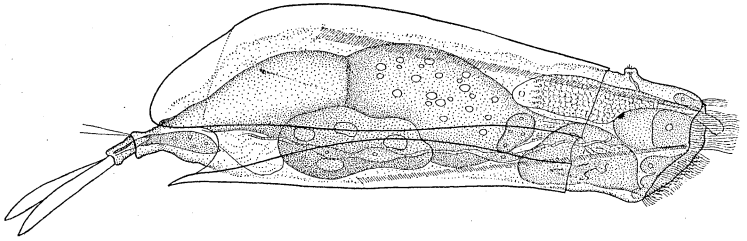

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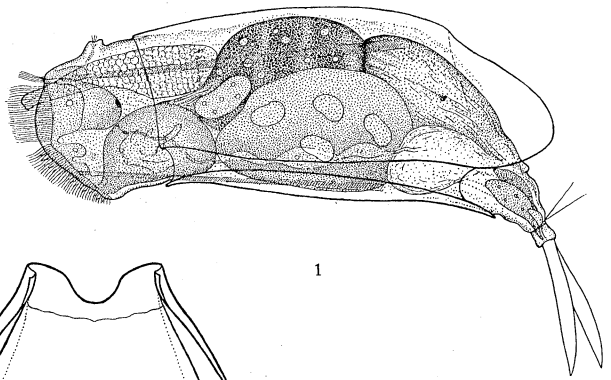

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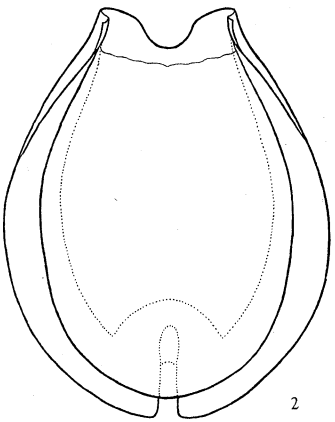

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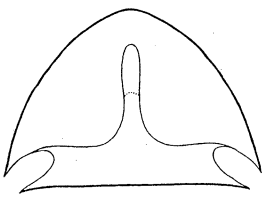

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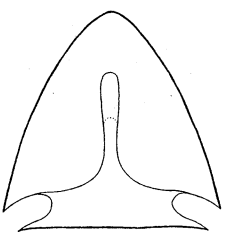

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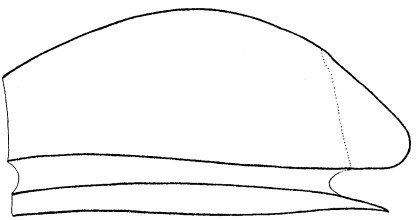

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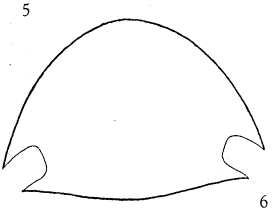

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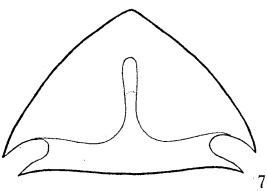

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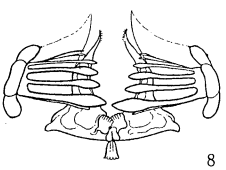

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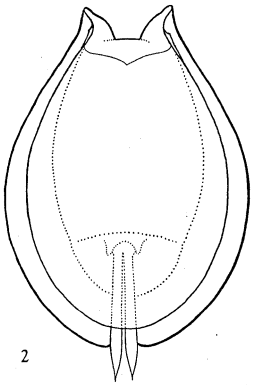

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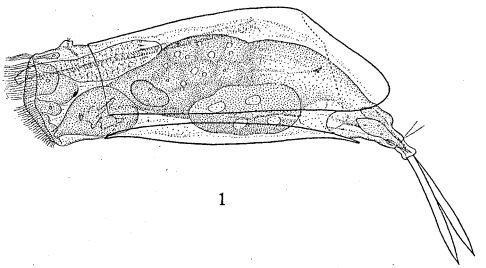

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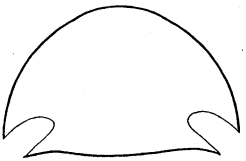

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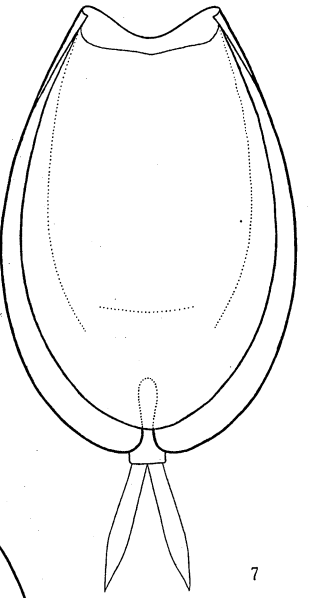

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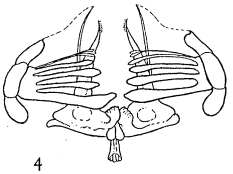

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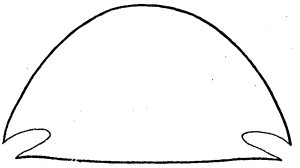

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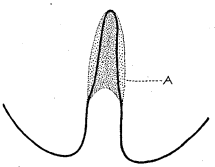

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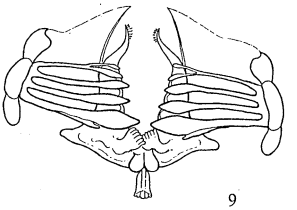

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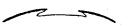

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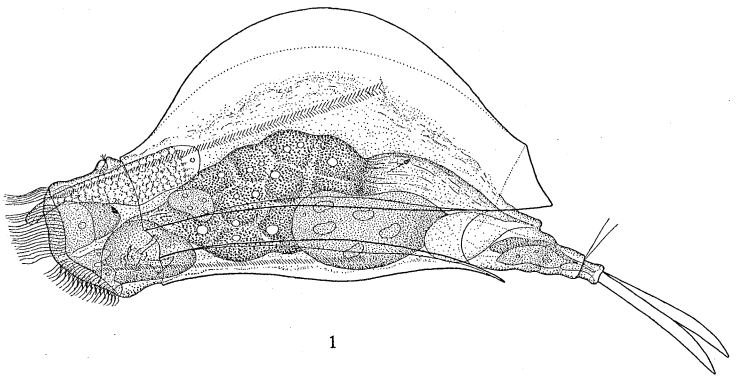

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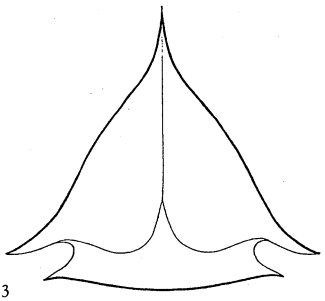

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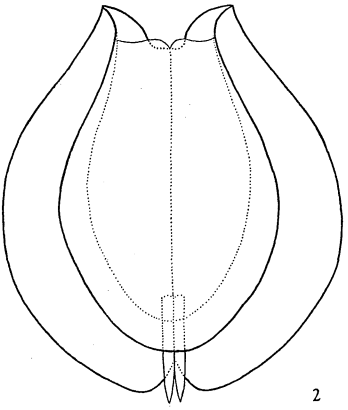

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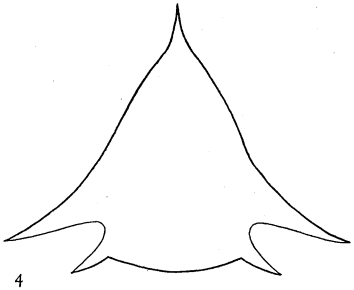

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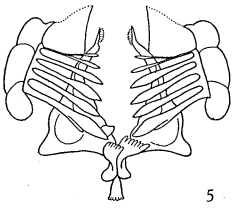

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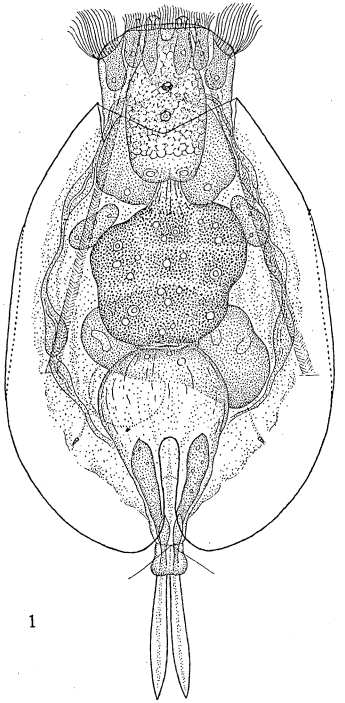

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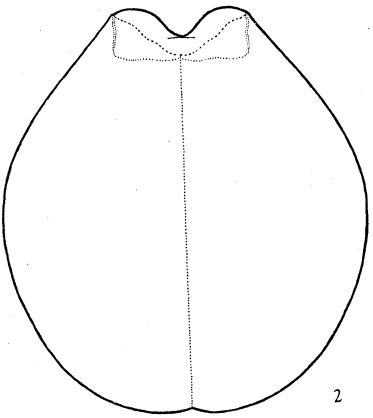

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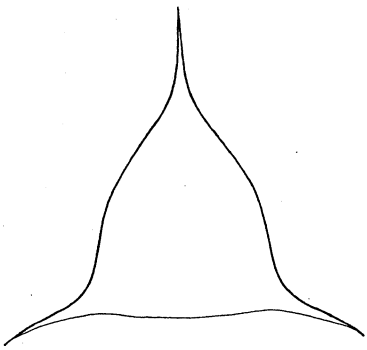

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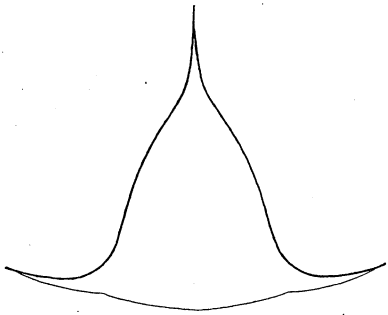

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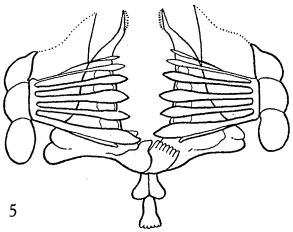

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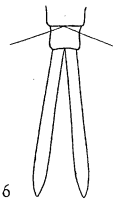

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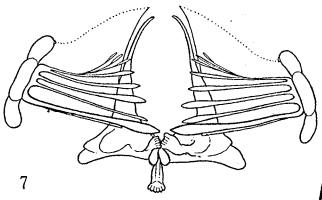

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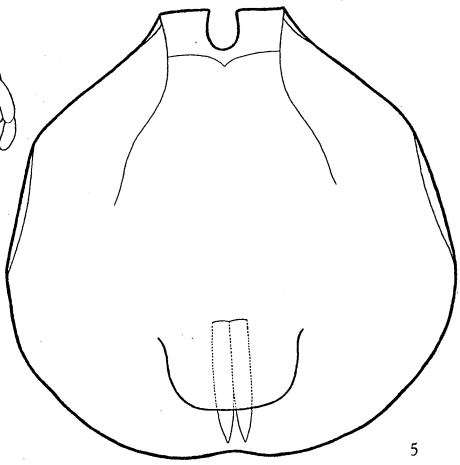

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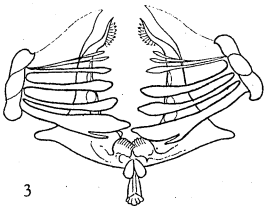

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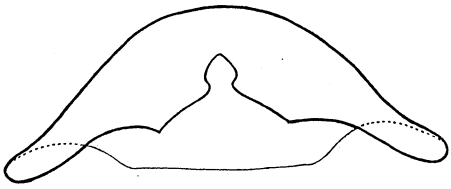

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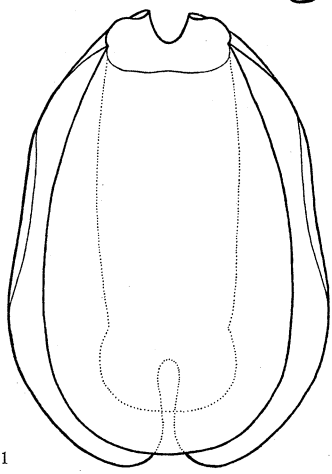

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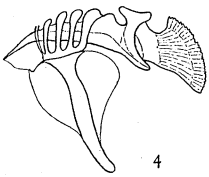

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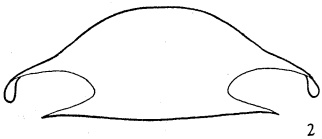

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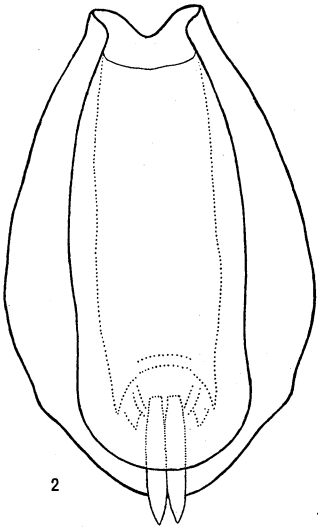

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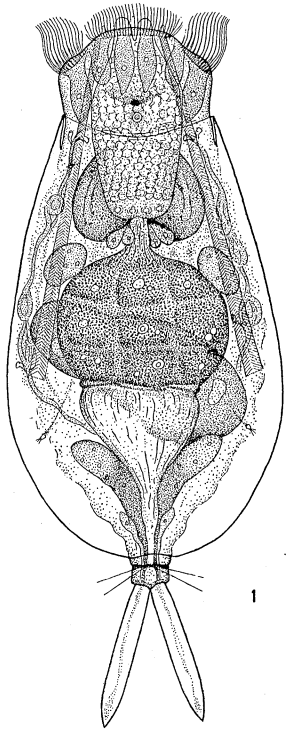

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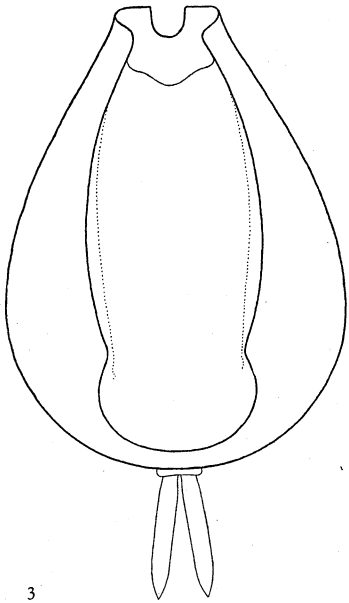

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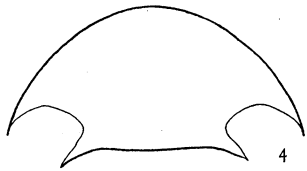

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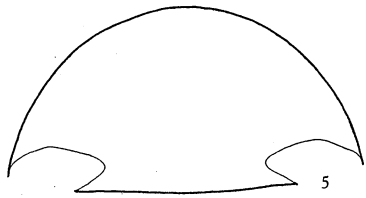

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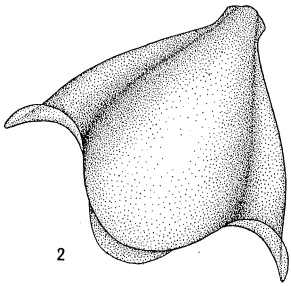

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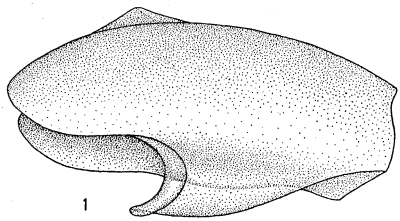

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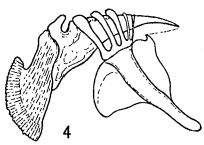

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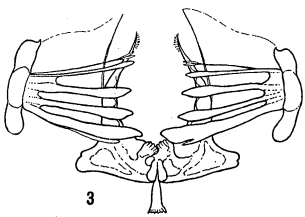

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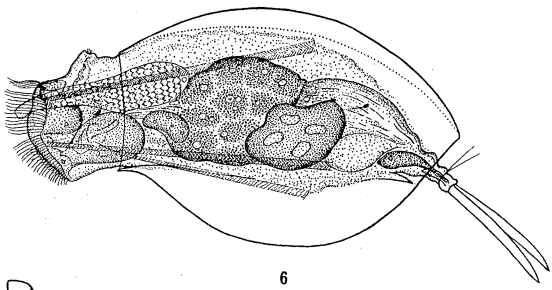

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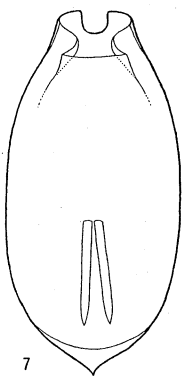

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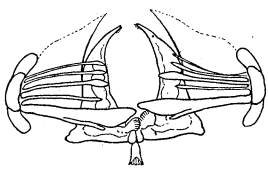

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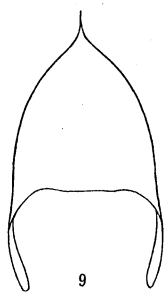

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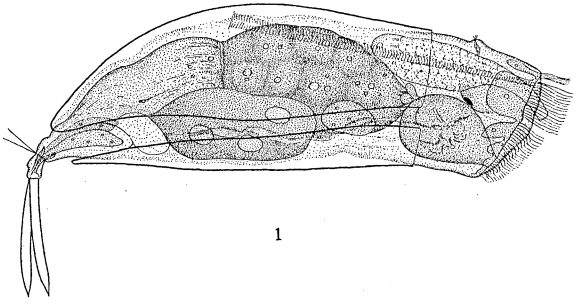

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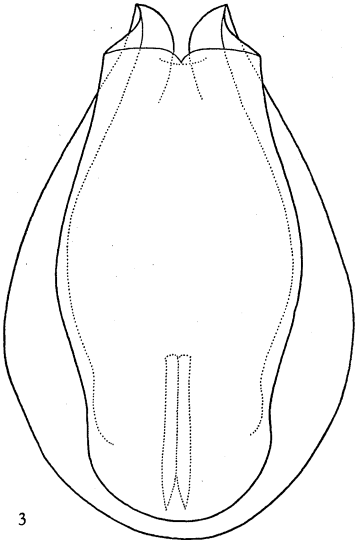

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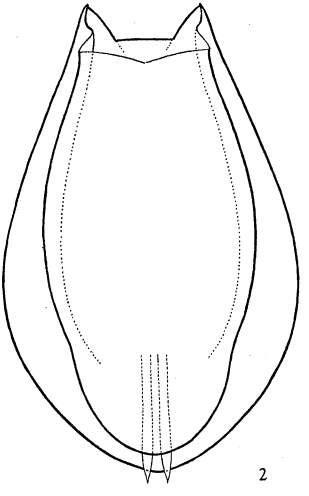

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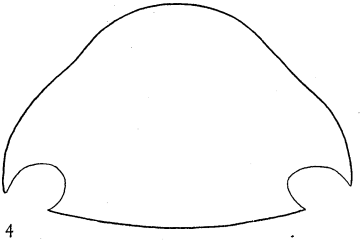

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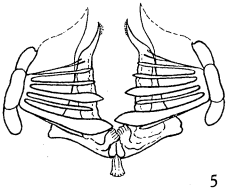

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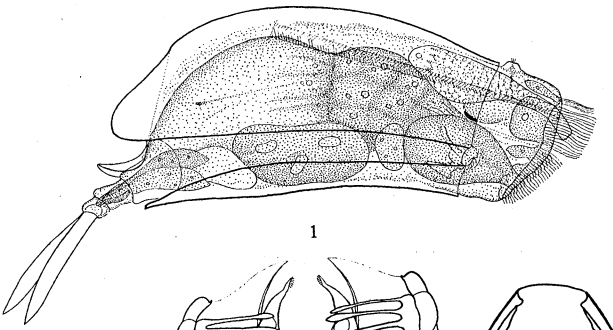

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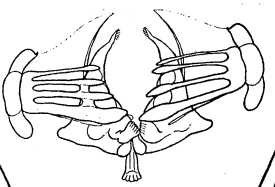

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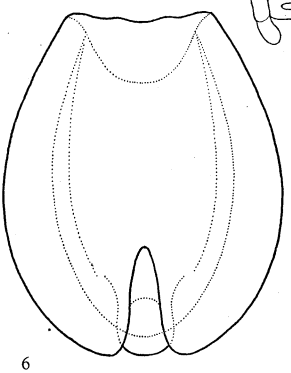

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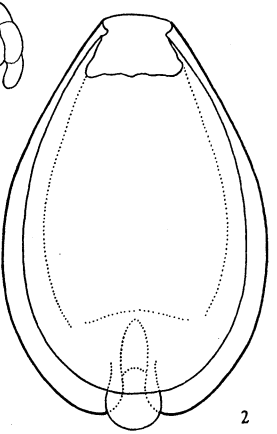

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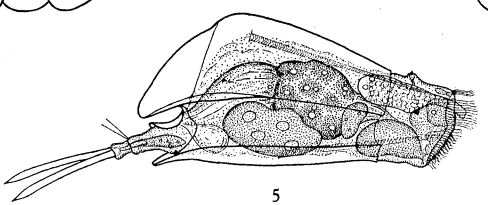

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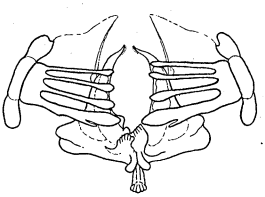

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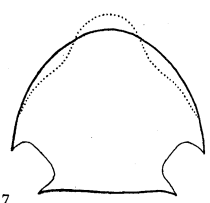

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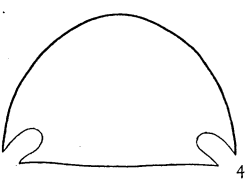

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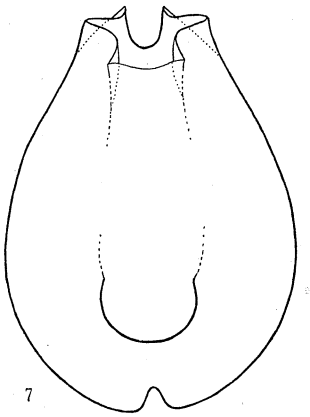

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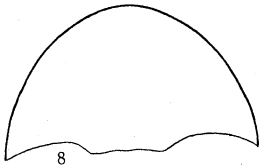

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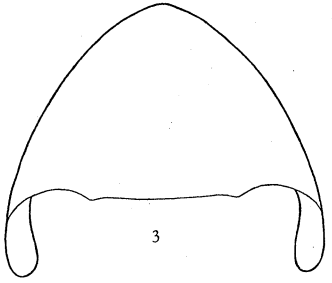

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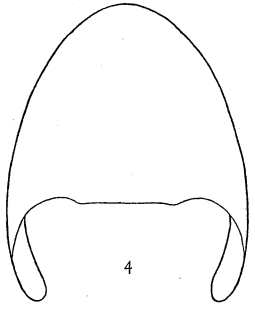

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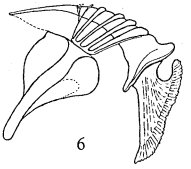

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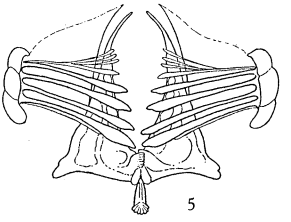

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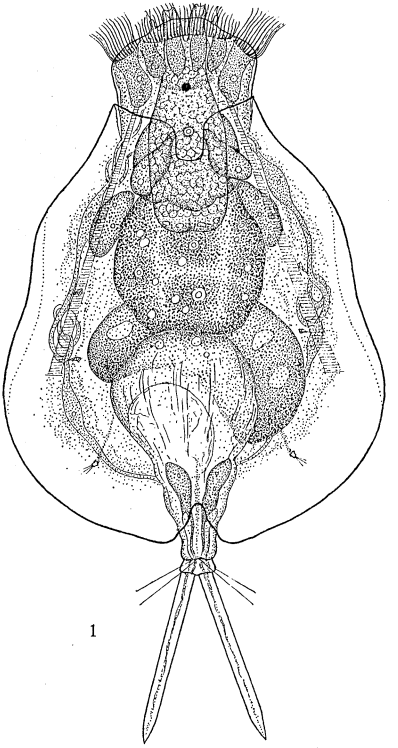

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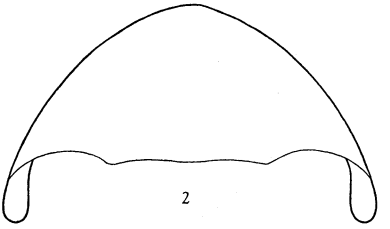

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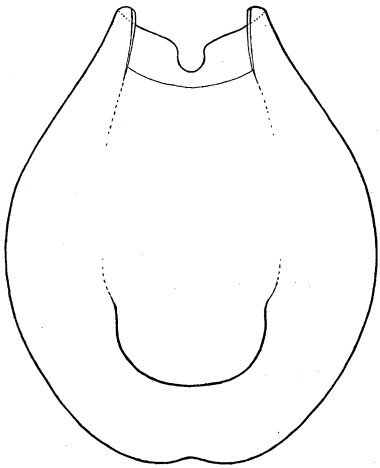

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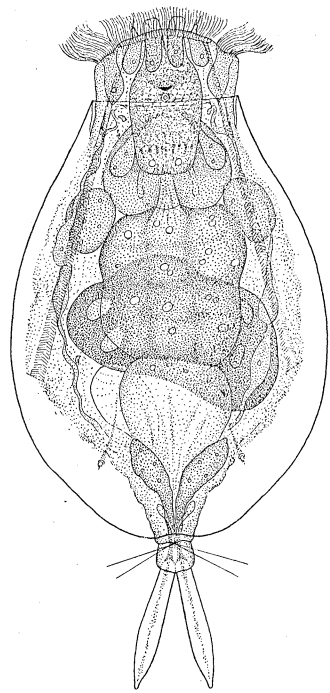

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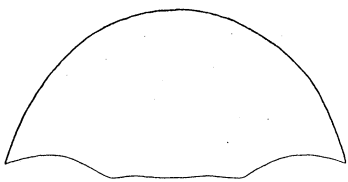

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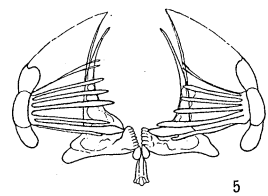

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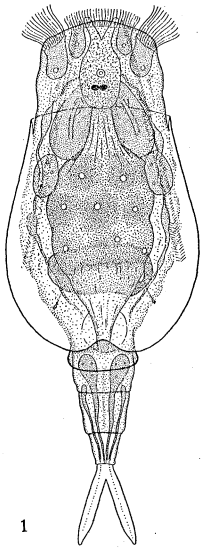

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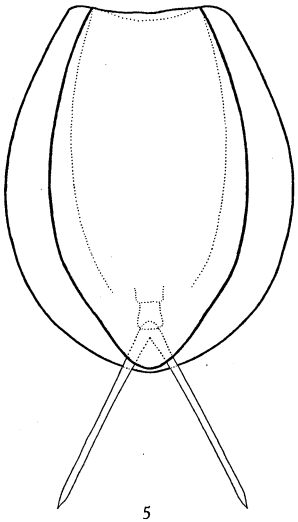

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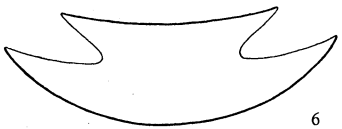

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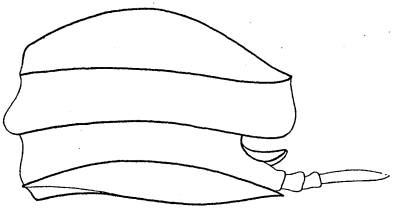

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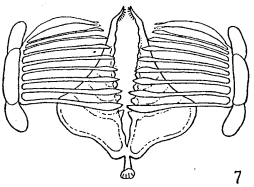

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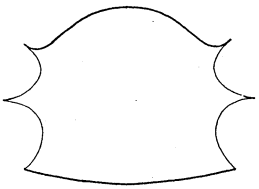

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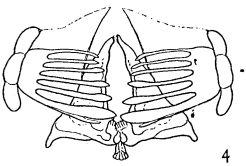

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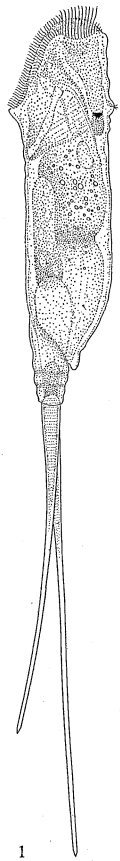

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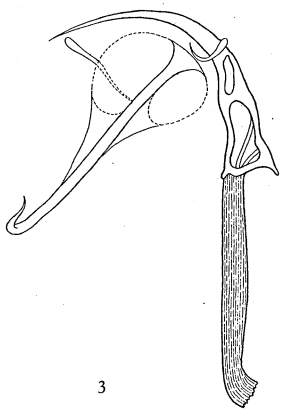

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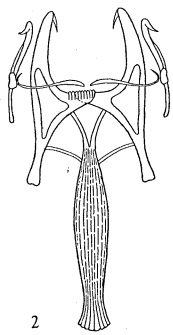

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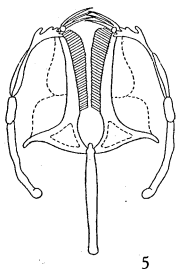

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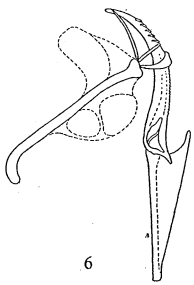

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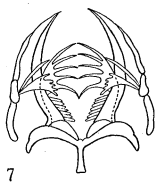

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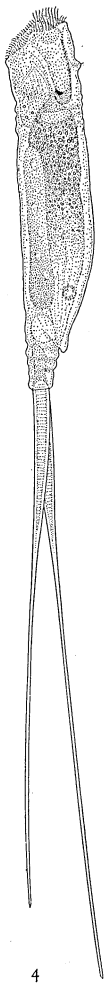

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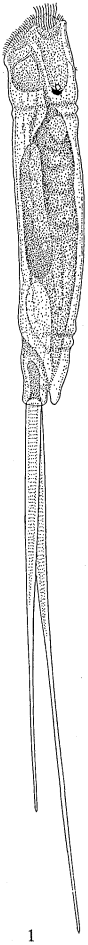

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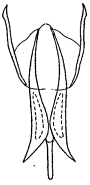

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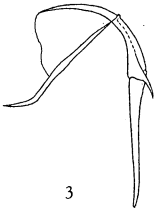

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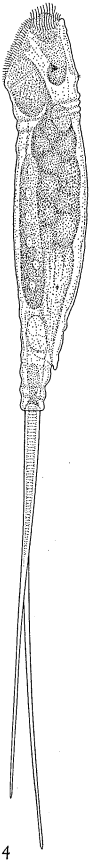

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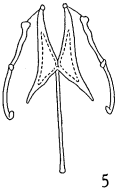

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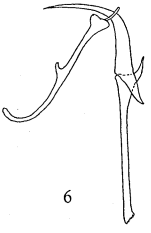

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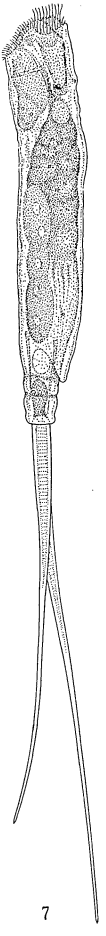

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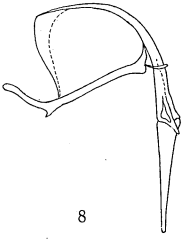

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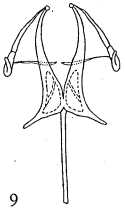

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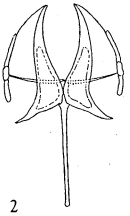

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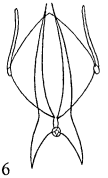

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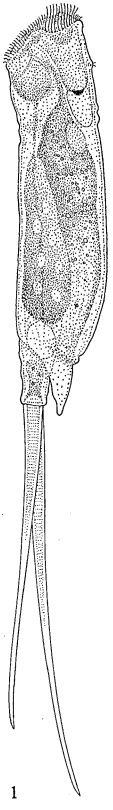

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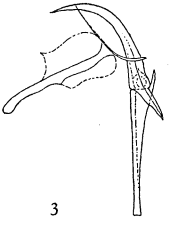

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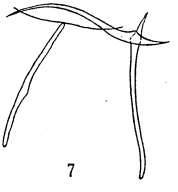

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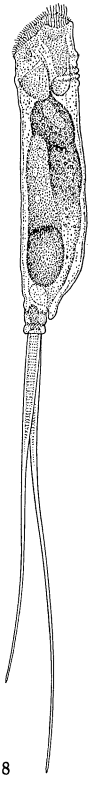

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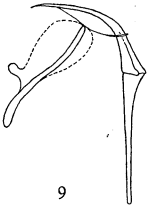

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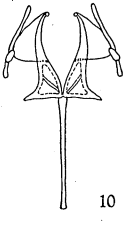

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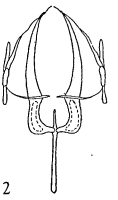

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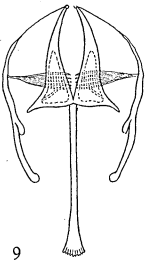

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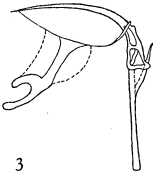

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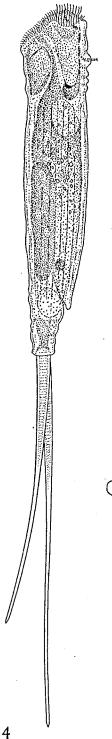

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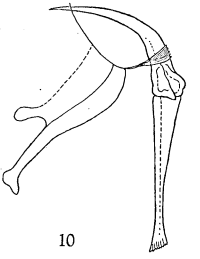

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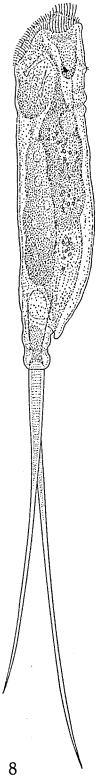

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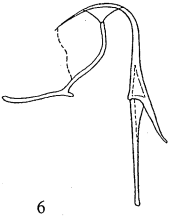

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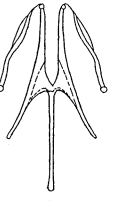

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