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TRANSACTIONS

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OF

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VOL. XXVI

NATURALE SPECIES RATIOQUE

MADISON, WISCONSIN

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THE BIRDS OF DANE COUNTY, WISCONSIN

A. W. SCHORGER

ANNOTATED LIST OF BIRDS

Part II

Family TYRANNIDAE. Tyrant Flycatchers.

122. *Tyrannus tyrannus* (Linnaeus). **Kingbird.** This flycatcher is a common summer resident. The average date of arrival is May 4; the earliest, April 24, 1913. It is common by May 15. In autumn, most of the birds have left by the middle of August, the average date of departure being Aug. 29; the latest, Sept. 15, 1917.

The Kingbird shows a decided preference for nesting near water.[1] When Lake Wisconsin was formed by the construction of the dam at Prairie du Sac, nests were common in the trees killed by the water, and frequently were placed only a few inches above it. Mr. Herbert Stoddard states in a letter: "I found over a dozen nests over the water at the same place the last week in June" (1919). Full sets of eggs have been found from June 4 to 25. I have seen young able to fly by July 5, but it is exceedingly doubtful that two broods are raised a season as has been claimed. White and bur oaks standing in the open are favorite nesting trees.

123. *Tyrannus verticalis* Say. **Arkansas Kingbird.** This species is of rare occurrence in the state and all the records are from Dane County. The first specimen was secured near Albion, June 11, 1877.[2] On July 31, 1927, G. E. French and W. E. Griffee[3] found two young and one adult of this species on the Nakoma golf course near Madison. The two young were collected by Mr. John Main on Aug. 1, and the adult female was taken by the writer the following day. The skin of one of the young is in the possession of Mr. Main, and those of the other two birds

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[1] Schorger, Auk 37 (1920) 144.
[2] Kumlien and Hollister, "Birds of Wisconsin," (1903) p. 80.
[3] Auk 44 (1927) 566.

are in my collection. In spite of the wandering tendencies of this species, it is probable that the young birds were reared in the county.

124. *Myiarchus crinitus* (Linnaeus). **Crested Flycatcher.** The Crested Flycatcher is a common summer resident in heavy timber, especially in the lowlands. It is particularly numerous in the Wisconsin River valley. The raucous notes of this bird are to be heard during the entire period of its presence with us. The average date of arrival is May 7; the earliest, April 26, 1925. In fall the average date of departure is Aug. 30; the latest, Sept. 12, 1915.

Norman Betts found a nest with young June 21, 1914. This species is noted for placing fragments of the cast skins of snakes in its nest, the latter being placed in a cavity in a tree.

125. *Sayornis phoebe* (Latham). **Phoebe.** The Phoebe is an abundant summer resident. It is the hardiest of our flycatchers, arriving on the average March 28. The earliest date is March 19 (1921 and 1927). After arriving it remains in the vicinity of water, especially about springs, where during late blizzards it survives on seeds and the hardy insects that are abroad. In fall it is widely distributed. The average date of departure is Oct. 14; the latest, Oct. 21.

The nest of this species is frequently so overrun with mites that it is surprising that the young survive. It is usually placed beneath bridges, on cliffs, or on buildings near water. Eggs have been found from April 22 to June 27. Full sets are not common until the second week in May. Late sets are probably due to destruction of an earlier nest.

126. *Empidonax flaviventris* (Baird). **Yellow-bellied Flycatcher.** Of all our flycatchers, the Yellow-bellied is the most easily overlooked. It occurs sparingly during the migration periods during which times, in my experience, it is always silent. Rich bottom woodlands with heavy undergrowth are preferred. It has been found in spring between May 12 and 30. The average date of arrival is May 20. Most of the records fall within the last ten days of the month. The fall records are scanty. The extreme dates are Aug. 12 to Sept. 5 (1927).

According to Kumlien and Hollister,[4] L. Kumlien found a nest

[4] "Birds of Wisconsin", (1903) p. 82.

with one egg and two young just hatched in a tamarack swamp near Albion, June 25, 1891.

127. *Empidonax virescens* (Vieillot). **Acadian Flycatcher.** The Acadian Flycatcher is an uncommon summer resident in the western portion of the county. The only locality within our boundaries where it seems to occur regularly is the wooded portion of the Wisconsin River valley at Mazomanie. I have also found it across the river on Otter Creek. Taylor[5] collected one May 25, 1921. I collected one of a pair at Cross Plains July 5, 1924, and one at Mazomanie May 31, 1925.[6] Eggs were found in Grant County on June 17, 1924.

This species is resident in heavy timber. A sight record is worthless. Possibly it can be distinguished in the field from the Least Flycatcher but not from Traill's Flycatcher. Fortunately the male at least has a very characteristic note, a loud *"pee-ee-yuk"*. I have not heard this call later than July 5.

128. *Empidonax trailli trailli* (Audubon). **Traill's Flycatcher.** A common summer resident, arriving on the average May 19. The earliest date is May 8, 1920. The fall migration is usually completed by Aug. 20. The latest date is Sept. 7. In contrast to the Least Flycatcher, this species avoids timber. During the breeding season it is found in two types of cover: clumps of dogwood, low willows, etc. in marshes; and in large areas of sumac on the uplands.

The nest is deep, and compact, resembling that of the Yellow Warbler. It is placed 3 to 8 feet, usually 6 feet, from the ground. Isolated clumps of bushes 30 to 50 feet in diameter never contain more than one breeding pair. This species shows great skill in keeping out of sight though its complaining notes prove it to be only a few feet distant. The earliest date on which a set of eggs (4) has been found is June 14 (1914). The average date for full sets, three eggs being more common than four, is June 20. On July 4, 1924, I found a nest with four eggs and a young Cowbird as large as a House Wren. About 10 per cent of the nests are parasitized by the Cowbird. The young Flycatchers develop rapidly and have been noted on the wing by July 12.

129. *Empidonax minimus* (Baird). **Least Flycatcher.** The

[5] Auk 39 (1922) 273.
[6] Auk 44 (1927) 235.

Least Flycatcher is a very common summer resident and is the most widely distributed of all our flycatchers. It shows a preference for open woodlands, but is also to be found in gardens, orchards, and thickets. The average date of arrival is May 7; the earliest, May 2 (Taylor). The average date of departure in fall is Sept. 13, the latest, Sept. 29, 1929.

I have found nests from five to fifty feet from the ground. They usually contain a few feathers. Deposition of eggs begins June 3. This is the only one of our small flycatchers to lay white, or at most faintly dotted eggs.

130. *Myiochanes virens* (Linnaeus). **Wood Pewee.** The Wood Pewee is a common summer resident in town and country where there are large trees sufficient to form a wood or grove. The earliest spring record is May 10 (Taylor). My notes show that during a period of seventeen consecutive years the Wood Pewee arrives from May 15 to 24, the average date being May 19. Betts had May 17 to 24 for the first arrivals. Kumlien and Hollister[7] state that it arrives April 28 to May 5. This difference is not easily explained. The average date of departure in autumn is Sept. 19; the latest, Oct. 1, 1916.

If nidification has a taxonomic value, then this species and the Acadian Flycatcher are closely related. The nests of both species are usually loosely constructed platforms. Mr. George French found a nest with eggs June 27, 1926.

131. *Nuttallornis borealis* (Swainson). **Olive-sided Flycatcher.** The Olive-sided Flycatcher is a rather uncommon migrant. It has been observed in spring from May 10, (1916) to May 27. Arrival before May 15 is rare, most of the records falling within the period May 16 to 20. In fall it has been noted from Aug. 16, (1930) to Sept. 5, (1921). It has been my experience that the occurrence of this species is very irregular. Beginning with the spring of 1926, I made a special effort to collect a specimen. Success was not attained until Aug. 25, 1929, when a male was taken near Madison.[8] On the other hand, I saw it during the season of 1930 on five occasions as follows: May 25; Aug. 16 (specimen collected); Aug. 23; Aug. 24; and Aug. 29.

During migration the Olive-sided Flycatcher occupies a dead limb on the top or side of a tree from which it watches for pass-

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[7] *L. c.*, (1903) p. 82.
[8] Auk 47 (1930) 424.

ing insects. I have seen one dart a distance of 300 feet, capture an insect and return to the same perch. According to my observations, the long flights are the result of a chase rather than of the victim being sighted at so great a distance, for the bird frequently rises to a considerable height before flying horizontally.

Family ALAUDIDAE. Larks.

132. *Otocoris alpestris alpestris* (Linnaeus). **Horned Lark.** The Horned Lark is an irregular winter visitor. I took one from a flock of ten Jan. 1, 1914. Mr. Clarence Jung found some near Madison Dec. 20, 1920. Mr. Warner Taylor has furnished the following data: eight seen Feb. 22, and four Feb. 27, 1917; one, possibly the same bird, seen Feb. 16 and 23, and March 9, 1919; two, Feb. 25, 1920; one, March 22, 1922; three, Jan. 26, 1923; and a flock of about 100, Nov. 1, 1925. It was common again in January and February 1930.[9]

133. *Octocoris alpestris hoyti* Bishop. **Hoyt's Horned Lark.** This subspecies should be sought in the flocks of Horned Larks. I took a male Feb. 2, 1930,[10] and Mr. John Main[11] collected one the same day.

134. *Otocoris alpestris praticola* (Henshaw). **Prairie Horned Lark.** Common summer resident. A few are to be found throughout the winter unless the weather is exceptionally severe. Most of the birds have passed south by December to reappear again from the middle of February to the middle of March. The weak, twittering note of this species simply comes out of space. All points of the compass may be searched before the author is seen in wavering flight.

The eggs may be deposited by the middle of March but the survival of so early a nest is exceptional.

Family HIRUNDINIDAE. Swallows.

135. *Iridoprocne bicolor* (Vieillot). **Tree Swallow.** The Tree Swallow is a common summer resident. In fall, especially, it collects in enormous flocks that roost in the marshes. The average date of arrival is April 12; the earliest, March 27, but

[9] Main, Auk 47 (1930) 578; Schorger, *ibid.* 424.
[10] Auk 47 (1930) 424.
[11] Auk 47 (1930) 579.

March arrivals are rare. The early migrants are frequently reduced to a pitiable state by cold weather. On the morning of April 8, 1928, during a northwest snowstorm, the temperature being 28 degrees, I found a flock on a tree sheltered by the bluff at West Point. The birds appeared barely able to maintain their perch. The average date of departure is October 11; the latest, Oct. 22, 1916.

The Tree Swallow nests preferably in dead trees in marshes, or near water. If protected against the English Sparrow, it will breed in nesting boxes in town. Eggs have been found from May 20 to June 16.

136. *Riparia riparia* (Linnaeus). **Bank Swallow.** The Bank Swallow is a common summer resident, arriving late in April or early in May. The average date is May 4; the earliest, April 13 (Taylor). The bulk of the species departs in August, but a few birds remain until Sept. 11.

This species nests in large colonies in the sandy banks of the Wisconsin River, and in sand and gravel pits. It is quick to take advantage of suitable sites. During the building of the University Stadium in 1916, a large flock took possession of a mound produced during construction of the bleachers. On May 24, 1929, I noticed a flock of about 30 Bank Swallows about the excavation for a dwelling in Shorewood. Tunnels up to 18 inches in length had been excavated in a layer of sand about four feet beneath the surface. The entrance to the nest is usually oval. The nest cavity contains a thin layer of coarse grass and feathers upon which the eggs are deposited, chiefly in the period May 30 to June 6. It is not unusual for the parents to be killed by caving in of the earth.

137. *Stelgidopteryx serripennis* (Audubon). **Rough-winged Swallow.** This species is a common summer resident. The average date of arrival is April 15; the earliest, April 5, 1913. The fall migration is completed in August, the latest date being Aug. 22, 1914 (Betts). In the Madison region the first arrivals are usually noted near Black Hawk's Cave on Lake Mendota.

Unlike the Bank Swallow, the Rough-winged Swallow never nests in large colonies. It is not unusual, however, to find a few of this species nesting in a colony of Bank Swallows. The nests are placed in crevices of rocky cliffs along the lake shores, in the stone foundations of bridges, and in sand and gravel banks.

Birds have been seen carrying nesting material as early as May 3. Deposition of eggs is very irregular and extends from May 15 to June 25.

138. *Hirundo erythrogastra* Boddaert. **Barn Swallow.** This species is a common summer resident. It is more widely distributed during the breeding season than any of our other swallows, but numerically it ranks low. The acquired habit of nesting in barns renders it subject to constant persecution by the English Sparrow. The average date of arrival is April 19; the earliest, April 13 (1924 and 1929). The average date of departure in fall is Sept. 16. It has not been seen later than Sept. 26.

The Barn Swallow usually nests in barns and other buildings, and occasionally under bridges. The case of nesting on cliffs on Lake Mendota[12] is a reversion to a habit that prevailed previous to settlement of the country.

139. *Petrochelidon lunifrons lunifrons* (Say). **Cliff Swallow.** The Cliff Swallow is a common migrant and locally common summer resident. It now belies its name having taken to nesting under the eaves of buildings, nests on cliffs being the exception.[13] On May 31, 1919, I found a small colony of Cliff Swallows nesting on a cliff at Lake Wisconsin. Here, advantage had been taken of cavities in the rocks for the nest proper, only the tubular entrance being made of clay.[14]

This species nests abundantly in the eastern part of the county near Deerfield. On June 27, 1926, I found a new colony of 70 nests. The owner of the barn stated that he had not had Cliff Swallows for twelve years and that the birds had come to his place June 15. Inquiry revealed that there was a large colony at the Boneman farm a mile distant. The size of this colony was amazing, 456 nests being counted. All but 38 were located on the east side of the barn. Here there were three and four tiers of nests. The colony has existed for about 40 years due to Mr. Boneman's commendable protection. Slats have been nailed horizontally to help keep the nests in place. Unremitting warfare is waged against the English Sparrow that throws both

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[12] Betts, Wilson Bull. 28 (1916) 72.

[13] G. W. Featherstonhaugh visited the shot tower near Spring Green on June 1, 1837, and mentions that there was a large colony of [cliff] swallows on the face of the sandstone escarpment. ("A Canoe Voyage up the Minnay Sotor", London. 1847, Vol. 2, p. 111.).

[14] Auk 37 (1920) 143.

eggs and young from the nest. The Swallows make no attempt to defend themselves. The birds arrive in numbers about May 10 and remain about the colonies until Aug. 15. Full sets of eggs are to be found the end of May.

The earliest date of arrival is April 27 (Taylor). The Cliff Swallow departs in September, the latest date being Sept. 20, 1914.

140. *Progne subis subis* (Linnaeus). **Purple Martin.** Owing to the readiness with which the Purple Martin has taken to houses provided for it, this has become the most familiar of our swallows. It arrives somewhat earlier even than the Tree Swallow, the average date being April 7. In the years 1925 and 1929 it arrived March 30. The average date of departure in fall is Aug. 21; the latest, Aug. 29, 1926.

In its domestic economy, the Purple Martin is both dilatory and slovenly. While the gathering of nesting material may start the first week in May, eggs are usually not deposited before the first week in June. From the four to six eggs, perhaps two young will be reared successfully. Protracted cold rains may cause the abandonment of eggs and young.

Family CORVIDAE. Jays and Crows.

141. *Cyanocitta cristata cristata* (Linnaeus). **Blue Jay.** The Blue Jay is a common permanent resident. There is, however, a small but well defined migration during the first three weeks in May, and the latter part of September and first part of October. It is as numerous in town as in country. The beauty of the Jay's plumage and its impertinent ways enliven our dreary winters. This more than compensates for its occasional raids on the nests of other birds. Though noted for its raucous *"jay"*, this species has some very musical notes. It is no mean mimic. I have heard the notes of the Crow and Red-tailed Hawk imitated perfectly. This play seems to be indulged in most frequently in winter.

The Blue Jay has great antipathy towards the raptors. One of my most interesting experiences was watching a flock of Blue Jays mobbing a Sharp-shinned Hawk. Special attention to its alarm notes will lead to the discovery of hawks and owls that would otherwise be overlooked.

Full sets of eggs have been found from April 27 to June 3, the majority between May 5 and 15.

142. *Corvus brachyrhynchos brachyrhynchos* Brehm. **Crow.** Common permanent resident, less numerous in winter. The migrations take place in March and October. There are winter roosts to which thousands of birds repair towards evening after having spent the day foraging at great distances. These roosts are shifted under persecution. A very large roost that existed at Sun Prairie the winter of 1926-7 was broken up by shooting. The formation of roosts begins in July after the young are on the wing. The oak thicket at Sunset Point near Madison has been a favored place. On July 25, 1922, I counted 270 between 7:20 and 7:30 P. M. The birds arrived singly and in small flocks until over a thousand had assembled. From 100 to 200 birds usually winter here. Stoddard[15] made the interesting observation at Sauk City that the males assemble in roosts during the breeding season. This observation covered the period April 20 to June 13.

Nest building begins early. On March 11, 1923, I found a nest complete except for the soft lining. The latter usually consists of cow hair, twine, and bark of the wild grape vine. Full sets of eggs (5-6) have been found as early as April 4. Out of 27 nests examined, only one contained 7 eggs. Two sets found May 12 very probably represent a second attempt. Young able to fly have been noted by May 27.

Family PARIDAE. Titmice.

143. *Baeolophus bicolor* (Linnaeus). **Tufted Titmouse.** This species is of special interest owing to the gradual extension of its range northward. The specimen taken at Madison by N. C. Gilbert[16] on Dec. 15, 1900, remained for many years the only record for the state. Stoddard[17] collected one of a pair found at Sauk City on April 13, 1921, and determined that the species was established in the Wisconsin River bottoms. One was seen near Madison by Mr. Clarence Jung on Dec. 20, 1920. One was collected by Mr. Warner Taylor[18] on Feb. 1, 1921, and another was seen by him[19] on Dec. 26, 1922. I took my first specimen near Lake Wingra on Feb. 25, 1923.[20] It has since become a

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[15] Wilson Bull. 34 (1922) 76.
[16] Kumlien and Hollister, *l. c.*, p. 124.
[17] Wilson Bull. 34 (1922) 79.
[18] Auk 39 (1922) 274.
[19] Auk 40 (1923) 340; *cf.* 43 (1926) 382.
[20] Auk 41 (1924) 169.

regular winter visitor in the Madison region. During the past seven years it has been observed near Madison between Oct. 20 and March 21. It is usually associated with Chickadees. As evidence of the northward movement of southern species, I may mention seeing near Madison on Oct. 20, 1929, a Tufted Titmouse and a Redbellied Woodpecker within 100 feet of each other.

This species will probably become a permanent resident locally as it has in the Wisconsin River Valley. During the spring of 1925, I made a special effort to obtain a breeding record for this species and was finally successful.[21] On June 28 of this year while in the Mazomanie bottoms with Mr. Warner Taylor, I collected a young female from a family of five young and two old birds. This is the first known breeding record for the state.

144. *Penthestes atricapillus atricapillus* (Linnaeus). **Chickadee.** The confiding little Chickadee is a permanent resident. It is usually seen in small troops and sociability is dissolved only during the breeding season. During the winter, these troops have their camp followers in the shape of White-breasted Nuthatches, Downy Woodpeckers, and an occasional Brown Creeper, or Golden-crowned Kinglet.

Full sets of eggs, six to eight, have been found from May 11 to June 1. In spite of long acquaintance with this species, I only recently discovered that the Chickadee can produce a very startling, hissing note in defense of its nest.[22]

Family SITTIDAE. Nuthatches.

145. *Sitta carolinensis carolinensis* Latham. **White-breasted Nuthatch.** This species is a common permanent resident and is widely distributed. The prosaic, incessant search for insects up and down the tree is occasionally enlivened by the finding of a Screech Owl dozing in a cavity. The discovery is announced by a stuttering *turr-turr-turr,* so different from the *quank* of peaceful routine.

Nests with eggs were found by Mr. George French April 10 and April 27, 1927. These were found in decayed stubs. In Ohio, I usually found the nest in a natural cavity of a tree such as a knot hole or wind shake.

[21] Auk 44 (1927) 239.
[22] Auk 39 (1922) 423.

146. *Sitta canadensis* Linnaeus. **Red-breasted Nuthatch.** The Red-breasted Nuthatch is an erratic migrant and occasional winter resident in stands of conifers. Sometimes only one or two birds will be seen throughout the year. In 1916 it was common in both spring and fall, while in 1923, though only one bird was seen in spring, the species was observed regularly from Aug. 19 to Oct. 21. It seldom arrives in spring before the last week in April or the first week in May, and remains until the middle of the month. The earliest date is April 6, 1913 (Betts); the latest, May 27, 1917. In fall it occasionally arrives the end of August, but the main movement is in September. The latest date is October 21, 1923.

Between Nov. 11 and 14, 1913, I found this species very common in the hemlock-spruce forest near Herbster, Bayfield County.

Family CERTHIIDAE. Creepers.

147. *Certhia familiaris americana* Bonaparte. **Brown Creeper.** The Brown Creeper is a common migrant and winter resident. In appearance and action it expresses great humility. Small and of somber color, it matches the bark over which it creeps. The weak, strident notes are uttered half heartedly as if the author were abashed at revealing his existence. It is most numerous in spring during April. It departs from April 15 to May 11, the average date being April 28. In fall, it arrives usually during the last week in September. The average date is Sept. 27; the earliest, Sept. 18.

Family TROGLODYTIDAE. Wrens.

148. *Troglodytes aedon parkmani* Audubon. **Western House Wren.** An abundant summer resident. All the specimens taken by me in Dane County and elsewhere in the state are referable to this form.[23] It is doubtful if the eastern bird *T. aedon aedon* occurs in the state. It arrives the end of April or the first of May, the average date being April 30; the earliest, April 22, 1925. Departure in autumn usually takes place before the end of September, but sometimes in October. The average date for the last bird seen is Sept. 25; the latest, Oct. 7, 1917.

Full sets of eggs are most common during the first week in

[23] Auk 43 (1926) 557.

June. A nest with five eggs found May 20, 1921 is exceptional. The breeding season extends throughout the summer. Young have been seen in the nest as late as Aug. 26.

149. *Nannus hiemalis hiemalis* (Vieillot). **Winter Wren.** This bird is a common migrant. The loquacity of the species is a most useful aid in detecting the mouse-like form that is soon lost again under fallen timber or in rocky crevices. It is a rather common winter resident. I find it most frequently at this season at Merrill's Springs where there is an ideal combination of open water and rock faces overgrown with brush.

The Winter Wren occasionally appears the last of March, though usually not until early in April. The average date of arrival is April 5; the earliest, March 22 (Taylor). The average date of departure is April 28; the latest, May 15, 1927. It arrives in autumn the latter half of September or early in October. The average date is Sept. 29; the earliest, Sept. 16, 1916. The average date of departure is Oct. 26; the latest, Nov. 23, 1919.

150. *Thyomanes bewicki bewicki* (Audubon). **Bewick's Wren.** This wren is a recent accession to the state list. Through information furnished by Mr. Albert Gastrow, H. L. Stoddard[24] established the presence of two pairs of these wrens near Prairie du Sac in the spring of 1921. One of the birds, on the Dane County side of the river, was later studied by Warner Taylor and S. Paul Jones. Taylor[25] states that he saw one near Madison on April 15, 1916. A specimen was taken near Madison by him on April 30, 1923.[26]

The first breeding record is reported by Taylor.[27] In the spring of 1922, a pair nested twice in the bee-yard of Mr. E. D. Ochsner at Prairie du Sac. Mr. Ochsner informed me that a pair nested with him in the summer of 1927 and 1928, and though it appeared again in 1929, no nesting took place.

151. *Thryothorus ludovicianus ludovicianus* (Latham). **Carolina Wren.** This wren is known only as a casual fall visitor, but in time a nesting record will probably be established. Mr. Norman Betts[28] found one between Langdon Street and Lake Men-

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[24] Wilson Bull, 34 (1922) 78.
[25] Auk 39 (1922) 274.
[26] Auk 43 (1926) 382.
[27] Auk 39 (1922) 575.
[28] Auk 32 (1915) 237.

dota Sept. 17, 1914. This bird remained until Sept. 28. When seen by the writer on Sept. 20, it was in full song. Another was seen by Mr. Betts near Madison, July 18, 1915.[29]. Taylor[30] saw one in the river bottoms Sept. 17, 1923.

152. *Telmatodytes palustris iliacus* Ridgway. **Prairie Marsh Wren.** This is the breeding form. It is questionable if the Long-billed Marsh Wren *(T. p. palustris)* should be credited to the state.[31] The Prairie Marsh Wren is an abundant summer resident. During the breeding season it prefers the vicinity of cat-tails and the nest is usually placed in them. The spring migration is decidedly erratic. It may arrive at any time between March 25, (1928) and May 10. The average date is April 27. One seen at Lake Wingra, March 5, 1922, I suspected strongly of being a wintering bird. No positive proof of wintering was obtained until Dec. 31, 1928, when three were found at Mud Lake. The wrens were located in thick beds of cat-tails skirted by the open water of the Yahara River. I am not aware of other winter records for Wisconsin, and none were known to Barrows[32] for Michigan. Nearly all leave the county in September. The average date of departure is Oct. 8; the latest, Oct. 17, 1926.

These wrens expend their superfluous energy in building a large number of extra nests. Eggs are found more often in an old repaired nest than in one of new construction. The nests are usually built at the edge of the water or over it. Full sets of eggs have been found from May 30 to July 6. The last egg deposited is generally much lighter in color than the remainder.

153. *Cistothorus stellaris* (Naumann). **Short-billed Marsh Wren.** This wren is an abundant summer resident. It prefers the drier portions of the marshes covered with waving marsh grass. It arrives from May 3 to 10. One was collected May 1, 1927, this being the earliest date of arrival. The last of the species departs in October, the latest date being Oct. 19, 1913. The song of this species, *"tsuk-tsuk-chur-r-r-r-ur"*, may be heard in every direction in suitable localities, yet the authors are seldom seen for they keep well under cover.

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[29] Auk 33 (1916) 438.
[30] Auk 43 (1926) 382.
[31] Schorger, Auk 45 (1928) 106.
[32] "Michigan Bird Life", (1912), p. 679.

In contrast with the dark chocolate-brown eggs of the Prairie Marsh Wren, those of the Short-billed are usually pure white. The height of the nesting season is the second week in June.

Family MIMIDAE. Thrashers, etc.

154. *Dumetella carolinensis* (Linnaeus). **Catbird.** The Catbird is an abundant summer resident, nesting in parks and gardens almost as freely as in the country. The average date of arrival is May 6; the earliest, May 2. Departure in autumn takes place the end of September or the first of October, the average date being Oct. 1; the latest, Oct. 19, 1930. One seen by Paul Errington on Nov. 23, 1929 may represent a wintering bird. I collected one Dec. 20, 1925, with the expectation of obtaining a sound winter record since the bird's flight was normal.[33] It was found that the right humerus had been fractured and though it had healed perfectly, the accident might have prevented the bird from undertaking the long migratory flight.

Full sets of eggs have been found from May 21 to July 11. Most of the eggs are deposited the second week in June. The nest is usually placed in a thick bush or vine, and at a height of less than five feet. On May 30, 1922, I flushed a Catbird from a nest placed in the tip of an apple tree, twelve feet from the ground. The nest of this species is never parasitized by the Cowbird. I have inserted the eggs of the Cowbird and other species and found that they were always removed.

155. *Toxostoma rufum* (Linnaeus). **Brown Thrasher.** This fine singer is a common summer resident. It winters rarely. A sound specimen was taken Jan. 25, 1913.[34] The average date of arrival is April 23; the earliest, April 16, 1916. The average date of departure is Oct. 2; the latest, Oct. 17, 1914.

The nest is placed in a brush pile, thorny bush, or tangled vine; occasionally on the ground. The mother is very brave in defense of her nest, and frequently puts on so bold a front as to intimidate the marauding small boy. While the nest is being examined she will frequently take up a position within three feet of it. Nidification begins almost immediately after arrival. A nest found May 5, 1927, contained one egg. Full sets have been seen from May 10 to July 11, principally during

[33] Auk 43 (1926) 557.

[34] Schorger, Auk 31 (1914) 256.

the last half of May. Young able to fly have been noted by June 5.

Family TURDIDAE. Thrushes, Bluebirds, etc.

156. *Turdus migratorius migratorius* (Linnaeus). **Robin.** This familiar bird is an early migrant frequently appearing the first week in March. The average date of arrival is March 11; the earliest, March 2, 1913. A few winter commonly, and those seen in February obtain notice in the local papers under some such caption as "First Robin Seen". The arriving Robin has a characteristic call that is uttered with a pronounced movement of the wings and tail. Small roosts of Robins are found as early as the middle of June. Roosts of large size exist from July to the end of October. Most of the Robins have departed for the south before the first of November, but the migration is frequently not completed before the end of the month. The average date of departure is Nov. 15. Local cases of albinism have been reported.[35]

Full sets of eggs have been found from April 22 to July 8. Though two broods are usually reared, the prolongation of the nesting season is due mainly to the fact that remarkably few of the first attempts are successful.

157. *Hylocichla mustelina* (Gmelin). **Wood Thrush.** The Wood Thrush is a common summer resident. While preferring thick, moist woodland, it nests commonly in parks and gardens in Madison. The song, heard most frequently in the morning and in the evening, is of a beauty that commands attention. It arrives from May 3 to 14, the average date being May 9. Departure usually takes place before Sept. 18, the latest date being Oct. 12, 1913. One seen Nov. 6, 1927, had one of its primaries awry indicating an injury.

The nest is usually placed on a large lateral limb of a stunted tree at a height of five to seven feet from the ground. Bur oaks are used frequently. Full sets of eggs have been found from May 20 to July 4. This species is victimized commonly by the Cowbird whose eggs are accepted by the Wood Thrush even though they are deposited in the nest before her own. Young able to fly have been seen by June 18.

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[35] Betts, Auk 33 (1916) 438; Cahn, Wilson Bull. 33 (1921) 29.

158. *Hylocichla fuscescens salicicola* Ridgway. **Willow Thrush.** Twelve specimens taken during migration in Dane County belong to this subspecies.[36] The Veery, or eastern form *(H. f. fuscescens)* appears to be a rare bird in the state. This is quite the reverse of the statement of Kumlien and Hollister.[37] Through the courtesy of Mr. O. J. Gromme, the skins in the Milwaukee Public Museum were submitted to Dr. H. C. Oberholser for examination. Only one was found to be *H. f. fuscescens.* This bird, Museum No. $\frac{10130}{2741}$, taken at Milwaukee May 16, 1911, is the only specimen that I have been able to locate in the state.

The sweet, spiritual quality of the song of the Willow Thrush, like a lament for the passing day, is awesome as the evening shadows deepen in the northern forest. On rare occasions the song is heard during the spring migration.

The Willow Thrush is a common migrant, and (probably this form) an uncommon summer resident in the few small tamarack swamps that remain in the county. The average date of arrival is May 8; the earliest, April 30, 1914. The average date of the last bird seen is May 24; the latest, June 3. For some unknown reason this species is observed less commonly in fall. The migration lasts from Sept. 7 to 30.

159. *Hylocichla minima aliciae* (Baird). **Gray-cheeked Thrush.** The Gray-cheeked Thrush is a common migrant. It is the most wary and silent of our thrushes. On approach of the observer, it will fly to a considerable distance and in woodland will alight well up in a tree, where an alert posture is assumed. It arrives from May 6 to 15, and is sometimes common by the 12th. The average date of arrival is May 11; the earliest, May 3, 1928. The average date of departure is May 26; the latest, June 3, 1917.

The autumn migration occupies the month of September, the height being reached on the 20th. The earliest date is Aug. 25, 1928, the latest, Oct. 1, 1926.

160. *Hylocichla ustulata swainsoni* (Tschudi). **Olive-backed Thrush.** This thrush is also a common migrant, arriving and departing at about the same time as the Grey-cheeked Thrush.

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[36] Schorger, Auk 43 (1926) 557.
[37] "Birds of Wisconsin", (1903) p. 126.

The extreme dates of arrival and departure in spring are May 2, 1926, and May 30, 1917; in autumn, August 27, 1922 and October 6, 1929.

Under favorable light conditions it is readily possible to distinguish in the field the Olive-backed Thrush from the Grey-cheeked Thrush by the buffy eye ring and the buffy suffusion on the side of the throat. Needless to say there will be numerous occasions when identification will be impossible without collecting.

161. *Hylocichla guttata pallasi* (Cabanis). **Hermit Thrush.** The hardy Hermit Thrush frequently arrives before all the snow has melted; nor do late blizzards cause apparent discomfort. It arrives from the 3rd to 10th of April, the average date being April 7; the earliest, March 31, 1917. Final departure for the north takes place the first week in May, the average date being May 5; the latest, May 15, 1921.

The fall migrants arrive the end of September or first of October, the main movement occurring the middle of October. The average date of arrival is Oct. 4; the earliest, Sept. 27. It has not been noted later than Oct. 24 (1926).

162. *Sialia sialis sialis* (Linnaeus). **Bluebird.** One of the amenities of spring is the warble of the Bluebird. Scarcely has the snow departed before its call is heard high overhead. The average date of arrival is March 11; the earliest, Feb. 20, 1915, when spring was unusually forward. The average date of departure is Oct. 28. This species does not often linger later than the first week in November, the latest date being Dec. 3, 1916. Several remained in the Wingra region the winter of 1922-3, but wintering is exceptional.[38] The all too frequent custom of burning the woodlands in the environs of Madison may result in torture to the Bluebird, as it obtains most of its food from the ground. On several occasions after a fire I have seen Bluebirds painfully trying to alight on trees with feet burned by hot ashes.

Full sets of eggs have been found from April 19 to June 5.

Family SYLVIIDAE. Kinglets, Gnatcatchers.

163. *Polioptila caerulea caerulea* (Linnaeus). **Blue-gray Gnatcatcher.** The Gnatcatcher is generally distributed during

[38] Schorger, Auk 41 (1924) 169.

the breeding season but is most numerous in the woodlands along the Wisconsin River. This dainty species arrives the last week in April or the first of May. The average date is April 30; the earliest, April 17, 1927. The fall migration is usually completed by the end of August. The latest date is Sept. 13, 1914 (Betts).

The exquisitely constructed nest is usually placed in a bur or white oak. An apparently finished nest was found May 31, 1914. The eggs are deposited during the last two weeks of June. A sitting bird is no assurance that the nest contains eggs. I have made many tedious ascents only to flush the female from an empty nest.

164. *Regulus satrapa satrapa* Lichtenstein. **Golden-crowned Kinglet.** This tiny, energetic bird is a common migrant. A few usually winter, especially in the vicinity of conifers. This habit renders it difficult to set exactly the dates of arrival in spring and departure in fall. Taking into consideration the increase in numbers, this species arrives regularly the end of March or the first of April. The average date of arrival is March 30, the earliest, March 20, 1921, when eleven were seen. Departure takes place usually by the end of April, occasionally not until the first week in May. The average date is April 27; the latest, May 8, 1915.

Whether alone or in small groups, the Golden-crowned Kinglet frequently utters a call of four or five notes; this is of great assistance in the detection of fall migrants that arrive before the leaves have fallen. The vanguard arrives the last week in September or the first of October. The average date is Sept. 28; the earliest, Sept. 17, 1922. Final departure takes place the end of October or the first week in November.

165. *Corthylio calendula calendula* (Linnaeus). **Ruby-crowned Kinglet.** Common migrant, arriving and departing in spring somewhat later than its cousin. It usually arrives April 6 to 15, occasionally the end of March. The average date is April 9; the earliest, March 27 (Taylor). It departs on the average May 17, the latest date being May 22, 1915. Southbound migrants seldom arrive before the middle of September. The average date is Sept. 20; the earliest, Sept. 5, 1921. The average date of departure is Oct. 18; the latest, Nov. 1, 1916. This species is not known to winter.

Family MOTACILLIDAE. Pipits.

166. *Anthus rubescens* (Tunstall). **Pipit.** An irregularly common migrant. Some seasons it is not found at all. It frequents open fields occasionally, but is usually found in marshy ground or along the edges of ponds. The Pipit is an inconspicuous bird and frequently is not noticed until it springs into the air a few feet from the observer. The average date of arrival is May 9; the earliest, April 6, 1930. It has not been noted after May 23 (Betts). It returns in autumn the latter part of September. The average date is Sept. 22; the earliest, Sept. 15, 1928. The average date of departure is October 18; the latest, Oct. 21, 1928. In the fall I associate this species with Wilson's Snipe for it occurs in the same type of country as the latter.

Family BOMBYCILLIDAE. Waxwings.

167. *Bombycilla garrula* (Linnaeus). **Bohemian Waxwing.** This species is a decidedly irregular winter visitor. From Dec. 24, 1921 to March 22, 1922, it was fairly common.[39] The largest flock seen numbered twenty. This is the only winter that I have found them.

168. *Bombycilla cedrorum* Vieillot. **Cedar Waxwing.** This familiar species is erratic in its habits. It is usually a common summer resident. Some winters it is abundant, again, entirely absent. In spring it is most numerous in March, and in fall, in October. During winter and early spring it feeds on the fruits of the wild grape, bittersweet, hackberry, cedar, mountain ash, and barberry. Flocks will occasionally establish headquarters near a large bed of asparagus and feed on the fruits. There is a constant stream of birds to and from the bed. Since the fruits eaten consist largely of indigestible seeds, large quantities are eaten as digestion is rapid. When a large flock is at rest in a tree, the excrement strikes the leaves on the ground with a sound like hail.

It is doubtful if the Cedar Waxwing nests twice, yet there are two distinct nesting periods. In spring the eggs are laid the last two weeks in June and the nest is usually placed in an apple tree. The second period is in August, and the nest is usu-

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[39] Schorger, Auk 39 (1922) 574; Taylor, *ibid.* 40 (1923) 340.

ally placed in a box elder. In fall, I have found full sets of fresh eggs from Aug. 10 to 25.

Family LANIIDAE. Shrikes.

169. *Lanius borealis* Vieillot. **Northern Shrike.** This species is an uncommon winter visitor from Nov. 30 to March 30 (Betts). Having selected a suitable hunting ground, this being usually a thicket bordered by open fields, it will remain in the immediate vicinity throughout the winter. Usually only the brown, immature birds are present. On Feb. 24, 1917, I heard a Northern Shrike indulging in its curious medley of raucous and highly musical notes.

170. *Lanius ludovicianus migrans* Palmer. **Migrant Shrike.** The Migrant Shrike is a common summer resident. It arrives the first week in April, the average date being April 4; the earliest, March 25 (Taylor). Though this species is recorded as leaving the northern states in October or November, in this region departure appears to be completed in August. It has been noted but once later than Aug. 25, (1917), this being Nov. 8, 1914 (Betts).

The nest is usually located along a roadside, and in this region is generally placed in a tangled canopy of wild grape, less often in a hawthorne or other low tree with a dense crown. Full sets of fresh eggs have been found from April 26 to May 10. Two nests completely lined with feathers found April 21, 1929, were examined at intervals. On May 4, one nest was still empty, while the other contained but one egg. Young able to fly have been noted by June 2.

Family STURNIDAE. Starlings.

171. Sturnus vulgaris Linnaeus. **Starling.** The Starling is an European species that has become thoroughly established in the United States through the release of 40 pairs in New York City in 1890. Previous attempts at introduction were failures. It was first observed in Dane County March 18, 1928, when a flock of 40 was found near the outlet to Lake Monona.[40] It is now a permanent resident, though less common in winter than at other seasons. Susceptibility to severe cold renders the species migratory to a certain extent. One, shot from a mixed

[40] Schorger, Auk 45 (1928) 377; 46 (1929) 250.

flock of Starlings, Bronzed Grackles, Rusty Blackbirds, and Redwings feeding in a field October 26, 1929, had its stomach crammed with grasshoppers.

On June 8, 1929 a Starling was flushed from a hole containing an apparently completed nest. The latter was abandoned, probably as a result of enlargement of the hole for examination. Another nest found June 15 contained five young.

Family VIREONIDAE. Vireos.

172. *Vireo griseus griseus* (Boddaert). **White-eyed Vireo.** This appears to be a rare species in southern Wisconsin. One taken near Madison October 21, 1923,[41] is the only record for the county. The date indicates that the occurrence was accidental.

173. *Vireo belli belli* Audubon. **Bell's Vireo.** The first state specimen was taken by the writer near Lake Wingra July 3, 1914.[42] On June 9, 1922, Mr. Warner Taylor[43] found a pair nesting in the same region. He took the male and nest containing one egg. The species has since been found to be a regular summer resident in Grant County, particularly near Boscobel.[44]

The nest is usually placed in a dense growth of hazel or other brush at a height of two to five feet from the ground. Of three nests found in Grant County on June 2, 1928, two were empty and the third contained one egg. The following day, the first two nests each contained an egg; the third, two eggs of the owner and one of the Cowbird. This indicates rather close observance of the calendar.

174. *Vireo flavifrons* (Vieillot). **Yellow-throated Vireo.** This Vireo is a common summer resident. It prefers open stands of tall trees from which it seldom descends to low levels. It is fairly common even in the city of Madison. It arrives from the south from May 4 to 12, the average date being May 8; the earliest, May 2, 1913. The fall migration is usually completed by Sept. 15, the average date being Sept. 11; the latest date, September 24, 1916.

I have never been successful in locating more than one nest. On July 4, 1924, I found one with four fresh eggs. It was

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[41] Schorger, Auk 41 (1924) 347.
[42] Betts, Auk 31 (1914) 542.
[43] Auk 39 (1922) 575.
[44] Schorger, Auk 44 (1927) 237.

placed 38 feet from the ground in the tip of a black oak at the edge of the Wingra Woods. The nest was beautifully stuccoed with lichens, spider webs, willow "cotton", and many large fragments of the cocoon of a species of moth.

175. *Vireo solitarius solitarius* (Wilson). **Blue-headed Vireo.** The sharply defined markings of the Blue-headed Vireo give it a trim appearance lacking in other members of the family. This species is not known to nest in the county, but it is common during the migrations. It arrives early in May, the average date being May 7; the earliest, April 29, 1916. It has not been noted later than May 24. It is most numerous in the fall at the end of September. The average date of arrival is Sept. 20; the earliest, Sept. 3, 1923. The migration is usually over by Oct. 10, the latest date being Oct. 21, 1917.

176. *Vireo olivacea* (Linnaeus). **Red-eyed Vireo.** This is our most abundant vireo both as a migrant and summer resident. Usually it does not arrive before the middle of May, the average date being May 16; the earliest, May 7, 1915 (Betts). It rarely remains later than September. The average date of departure is Sept. 23; the latest, Oct. 2, 1926.

Eggs have been found from June 5 to July 7. It is unusual to find a nest that does not contain one or more eggs of the Cowbird. On several occasions I have found new nests with holes in the side such as would be produced by thrusting the finger through from the inside. On June 21, 1914, I stopped to examine a nest that was complete but empty on June 6. It was now inhabited by a pair of white-footed mice *(Peromyscus leucopus noveboracensis)* that had roofed it with leaves and made an entrance in the side. I am inclined to the opinion that these mice are occasionally destructive to eggs and young.

177. *Vireo philadelphica* Cassin. **Philadelphia Vireo.** This is one of the rarer vireos but of fairly regular occurrence. It is usually associated with warblers during the May and September migrations. The average date of arrival is May 19; the earliest, May 10, 1914. It has not been noted later than May 29, (1927). It appears in fall the end of August or the first of September. The earliest date is August 22, 1920. The average date of departure is Sept. 16; the latest, Sept. 23, 1917. Specimens have been taken for record on the following dates: Sept. 23, 1917; Aug. 30, 1919; and May 29, 1927.

FIG. 1. Nest of Bell's Vireo.

FIG. 2. Nest of Golden-winged Warbler.

178. *Vireo gilva gilva* (Vieillot). **Warbling Vireo.** The Warbling Vireo is a common summer resident. In contrast to our other vireos, it nests usually in shade trees, orchards and along the roadside, rather than in woodland. It sings from the day of arrival to departure. The average date of arrival is May 7; the earliest, May 2, 1914. It disappears by the middle of September, the average date being the 12th; the latest, September 26, 1920.

Family MNIOTILTIDAE. Wood Warblers.

179. *Mniotilta varia* (Linnaeus). **Black and White Warbler.** The Black and White Warbler is a common migrant. There are no breeding records, but a singing bird was found at Cross Plains July 26, 1925. It is frequently found in summer at Gibraltar Rock, Devil's Lake and adjacent places. The criss-cross method of progression used by this species in feeding on the trunks and limbs of trees is a characteristic procedure and is not employed by other members of the family. It arrives the last of April or the first of May, the average date being May 3; the earliest, April 19 (Taylor). The average date of departure is May 21; the latest, June 3, 1917. Fall migrants usually appear the end of August, the average date being Aug. 27; the earliest, Aug. 12, 1923. Migration is usually completed by the end of September the average date being Sept. 26; the latest, Oct. 7, 1923.

180. *Protonotaria citrea* (Boddaert). **Prothonotary Warbler.** This handsome warbler is a common summer resident in woods bordering the Wisconsin River and nests occasionally at Lake Koshkonong. Elsewhere in the county it is uncommon even as a migrant. It prefers swamps or low woodlands in the immediate vicinity of water. The nest is placed in a hole in a decayed stub usually six to ten feet from the ground; however, on one occasion I found a nest about 35 feet from the ground. It takes readily to bird boxes. It arrives about the 12th of May. The earliest date is May 3, 1913 when one was taken at Madison. There are few data on the fall migration. According to W. W. Cooke,[45] the birds leave the northern part of their range in the latter part of August.

On June 9 and 11, 1913, Stoddard[46] found five nests contain-

[45] Biolog. Survey Bull. No. 18, (1904) 26.

[46] Auk 34 (1917) 66; *cf.* Taylor, *ibid.* 39 (1922) 274; Schorger, *ibid.* 44 (1927) 237.

ing eggs or newly hatched young. I have found nests with eggs from May 31 to June 16.

181. *Vermivora pinus* (Linnaeus). **Blue-winged Warbler.** While a common summer resident in the bottom lands along the Wisconsin River,[47] the Blue-winged Warbler is uncommon even as a migrant in other portions of the county. The usual song is a drawling "*zwe-e-e-e-e-e ze-e-e-e-e-e.*" One day while watching a male, he suddenly ceased singing and gradually expanded his feathers as if his body were growing with an idea; then suddenly he dashed away to another perch only to begin singing again. It prefers open stands of trees and bushes where there is a luxuriant growth of grass. The earliest date of arrival is May 10 (Taylor). I have seen it on only two occasions in the immediate vicinity of Madison, May 18, 1924 and May 15, 1929. Insufficient observations have been made in the breeding region to furnish reliable data on the migrations.

On June 13, 1926, by watching the female, I found a nest of this species in a thick growth of weeds in the Mazomanie bottoms. It contained one addled egg. On the edge and bottom of the nest were deposits of fresh excrement indicating that the young had just left. These could not be found. The young are very precocious and will leave the nest before able to fly.

182. *Vermivora chrysoptera* (Linnaeus). **Golden-winged Warbler.** A common migrant and locally a rather common summer resident, especially at Cross Plains and Mazomanie. It arrives May 10 to 15, the average date being May 12. My earliest record is May 9 (1915 and 1927). Taylor has the exceptionally early date of April 29. Most of the migrants have passed northward by May 24, though it has been seen in the vicinity of Madison, where it does not breed, as late as May 31. The fall migration takes place early and is practically completed during the last week in August and the first week in September. The extreme dates are Aug. 20 (1921) and Sept. 11 (1921 and 1927).

A nest found at Cross Plains on June 13, 1925 contained one egg. When next visited, June 19, there were four eggs.[48]

183. *Vermivora ruficapilla ruficapilla* (Wilson). **Nashville**

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[47] Stoddard, Auk 34 (1917) 67; Taylor, *ibid.*, 43 (1926) 381; Schorger, *ibid.*, 44 (1927) 237.

[48] Schorger, Auk 44 (1927) 238.

Warbler. This warbler is a common migrant, more numerous in spring than in fall. It arrives early in May, the average date being May 6; the earliest, April 25, 1925. The migration is usually completed by May 20, the latest date being May 27, (1917 and 1926). The fall migration takes place between Sept. 1, (1915) and Oct. 12, (1930). The main movement takes place during the middle of the month. A sight record for Nov. 1, 1925 is recorded by Taylor.[49]

There are no nesting records for the county, though Stoddard[50] has found it during the breeding season in Sauk County.

184. *Vermivora celata celata* (Say). **Orange-crowned Warbler.** The Orange-crowned Warbler is a fairly common migrant. Unlike the Nashville, to which it has a general resemblance, it is usually found feeding in low growths two to ten feet from the ground. It arrives on the average May 4; the earliest, April 29, 1916. It has not been seen later than May 18, (1924 and 1927). It is a late fall migrant, the southward movement taking place largely during the month of October. The earliest date is Sept. 29, 1929; the latest, Oct. 22, 1922. Taylor[51] found one on the exceptionally late date of Dec. 10, 1925.

I have taken specimens on the following dates: May 9, 1915; May 4, 1918; May 1, 1920; May 12, 1929. John Main took one on May 18, 1927; and Warner Taylor,[52] one on Oct. 16, 1922.

185. *Vermivora peregrina* (Wilson). **Tennessee Warbler.** This is one of our commonest migrants among the warblers. In spring its loud song is uttered repeatedly. It arrives from May 8 to 17, the average date being May 13; the earliest, May 7, 1913 (Betts). The average date of disappearance is May 25; the latest, June 3, 1917. The first fall migrants are usually seen the latter part of August, the average date being Aug. 27; the earliest, Aug. 17, 1914. It is most common Aug. 29 to Sept. 11. The average date of the last one seen is Sept. 27; the latest, Oct. 11, 1913 (Betts).

186. *Compsothlypis americana usneae* Brewster. **Northern Parula Warbler.** A fairly common migrant. It is likely to be found breeding in any county in the state where there are

[49] Auk 43 (1926) 382.
[50] Wilson Bull. 34 (1922) 69.
[51] Auk 43 (1926) 382.
[52] Auk 40 (1923) 340.

tamarack swamps. The nest is placed in a bunch of usnea moss hanging from the branches of this tree. It is very versatile in the positions assumed in feeding and the generic name is derived from *Parus* due to the habit of feeding suspended with the back downward like a Chickadee. The average date of arrival is May 7; the earliest, May 2, 1913. The average date of departure is May 18; the latest, May 20. In fall it has been observed between the dates Aug. 30 (1919) and Sept. 12 (1920).

187. *Dendroica tigrina* (Gmelin). **Cape May Warbler.** A rather common migrant arriving on the average May 9; the earliest, May 5, 1915. The average date of departure is May 20; the latest May 27, 1917. The fall migration lasts from Aug. 22 (1920) to Sept. 17 (1916).

188. *Dendroica aestiva aestiva* (Gmelin). **Yellow Warbler.** The Yellow Warbler is an abundant migrant and summer resident. This is probably the best known of all warblers from its striking yellow color and habit of nesting in bushes in lawns and parks. It arrives the first week in May, the average date being May 4; the earliest, April 28, 1914. The fall migration is early, the average date of the last bird seen being Aug. 14; the latest, Aug. 24, 1929.

Construction of the nest begins soon after arrival and it is completed about May 20. Full sets of eggs have been found from May 30 to June 19 (George French). I found one nest built over a nest of the previous season. When a Cowbird's egg is deposited before the eggs of the owner, it is covered by the construction of a second story or a new lining. The parents have been seen feeding young nearly to the time of final departure.

189. *Dendroica caerulescens caerulescens* (Gmelin). **Black-throated Blue Warbler.** Common migrant, favoring the low growths in woodland. The average date of arrival is May 8; the earliest, May 2, 1913. The migration is generally completed by May 23, the latest date being June 3, 1917. The fall migration sets in the end of August or the first week of September, the average date being Sept. 6; the earliest, Aug. 27, 1922. The average date of departure is Oct. 4; the latest, Oct. 14, 1928.

190. *Dendroica coronata* (Linnaeus) **Myrtle Warbler.** An abundant and early migrant. It arrives April 5 to 20, the aver-

age date being April 14. The earliest date is March 31, 1918, other early dates being: April 5, 1919 and 1921; and April 8, 1922. The average date of departure is May 18; the latest, May 27, 1917. The fall migration is erratic. The first migrants appear from Sept. 12 to Oct. 4, the average date being Sept. 26; the earliest, Sept. 6, 1914 (Betts). The main flight takes place in October, when these warblers swarm along bushy roadsides. They frequently remain until the end of October, the average date of departure being Oct. 24; the latest, Nov. 1, 1914 (Betts).

The first breeding record for this species in the state was obtained in Bayfield County in June, 1923.[53]

191. *Dendroica magnolia* (Wilson). **Magnolia Warbler.** The handsome Magnolia Warbler is one of the most abundant of our warblers. The average date of arrival is May 8; the earliest, May 2, 1913. The average date of departure for the north is May 25; the latest, June 3, 1917. The first southbound birds usually arrive the end of August, the average date being Aug. 28; the earliest, Aug. 20, 1921. Final departure occasionally does not take place until the first week in October. The average date is Sept. 27; the latest, Oct. 12, 1930.

One spring while watching a flock of warblers in some bushes, a Sharpshinned Hawk struck at a Magnolia Warbler but missed. The warbler dropped a few inches to a lower branch and commenced feeding again as unconcernedly as though nothing had happened.

192. *Dendroica cerulea* (Wilson). **Cerulean Warbler.** Dane County appears to be close to the northern limit of distribution of this species in the center of the state. It is a rare migrant in the vicinity of Madison but a regular summer resident in small numbers near Cross Plains and Mazomanie.[54] It prefers large stands of tall timber and seldom descends below the tree tops.

It arrives from May 4 (1913) (Betts) to May 9. I have not heard it sing later than July 4. It seems to disappear early in August.

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[53] Schorger, Auk 42 (1925) 68.

[54] Schorger, Auk 44 (1927) 238; Taylor, *ibid.* 43 (1926) 382; Stoddard, *ibid.* 34 (1917) 67.

193. *Dendroica pensyslvanica* (Linnaeus). **Chestnut-sided Warbler.** A handsome, abundant migrant arriving on the average May 8; the earliest, May 4 (1914 and 1928). The average date of departure is May 25; the latest, June 3, 1917. The fall migrants arrive in August, occasionally by the middle of the month, the average date being Aug. 24; the earliest, Aug. 14, 1921. The migration ends on the average Sept. 23. It sometimes remains until the end of the month, the latest date being Oct. 1, 1916. On this date one was seen on the ground trying to devour a large green caterpillar about two inches long and one-half inch in diameter.

This warbler nests abundantly in the northern half of the state and is a potential resident in all the southern half. It prefers fields overgrown with hazel and other brush, and second growth. It has not been noted in Dane County in summer. I have found it during the breeding season in Green and Grant Counties, and Stoddard,[55] in Sauk County.

194. *Dendroica castanea* (Wilson). **Bay-breasted Warbler.** A common migrant. Some seasons it is much more numerous than others. As a rule it is more common in fall than in spring, the great majority of the migrants being young birds. This species arrives from May 9 to 17, the average date being May 13; the earliest, May 6, 1916. The average date of departure is May 25; the latest, June 3, 1917. Fall migrants usually appear during the last ten days of August, the average date being Aug. 27; the earliest, August 17, 1924. The average date of departure is Sept. 22; the latest, Oct. 12, 1930.

195. *Dendroica striata* (Forster). **Black-poll Warbler.** A loud and persistent singer, common during the spring migration. It is a late migrant, usually arriving after the middle of May. The average date is May 17; the earliest, May 10, 1914. The average date of departure is May 28, though in some years it remains into June. A singing bird was observed as late as June 13, 1925.

The autumn migration offers a difficult problem owing to the close resemblance of the Black-poll Warbler in fall plumage to the young of the Bay-breasted Warbler. I have never obtained a fall record. Specimens taken on suspicion proved to be *D.*

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[55] Stoddard, Wilson Bull. 34 (1922) 69.

castanea. Betts gives the dates Sept. 7 and 27 (1913), though as far as I am aware no birds were collected. Kumlien and Hollister[56] state that it is common "during the latter half of September and well into October". Cooke[57] gives for Chicago the extreme dates Aug. 23 and Oct. 12.

196. *Dendroica fusca* (Műller). **Blackburnian Warbler.** This handsome warbler is a common migrant, arriving on the average May 7. The earliest date is April 29, 1916. It departs on the average May 23, the latest date being May 30, 1917. The fall migration begins the latter part of August, occasionally by the middle of the month. The average date is Aug. 23; the earliest, Aug. 14, 1921. The migration is usually completed by the middle of September, the latest date being Sept. 19, (1920 and 1926).

Though not known as a summer resident, there is a good chance of finding this bird nesting in the county.

197. *Dendroica virens* (Gmelin). **Black-throated Green Warbler.** Common migrant, arriving usually the first week in May, occasionally by the end of April. The average date is May 4; the earliest, April 24, 1921. The average date of departure is May 23; the latest, June 6, 1914. In fall, migrants appear the end of August or early in September. The average date is Aug. 31; the earliest, Aug. 25, 1923. The average date of departure is Oct. 1; the latest, Oct. 23, 1928. Taylor[58] observed one Nov. 1, 1925.

198. *Dendroica pinus* (Wilson). **Pine Warbler.** This warbler is a fairly common migrant, but none of the local observers find it every season. Mr. Warner Taylor informs me that he has seen it on only 4.2 per cent of his field trips during the seasons when this species should be migrating. It arrives early, the average date being April 27; the earliest, April 23, 1915. It has been seen most frequently between May 11 and 20, the latest date being May 21, 1925. The average date of arrival in fall is Sept. 9; the earliest, Aug 10, 1930 (Pine Bluff). The average date of the last one seen is Sept. 23; the latest, Oct.

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[56] "Birds of Wisconsin", (1903) p. 114.
[57] Biol. Survey Bull. No. 18, (1904) 79.
[58] Auk 43 (1926) 382.

4, 1923 (Taylor). Norman Betts has the exceptionally late date of Nov. 8, 1914.

It is a rather common summer resident in the northern part of the state where there are stands of pine. At Hazelhurst, Oneida Co., on Aug. 15, 1929, I saw a pair of adults and three young. The latter were being fed by the female. The male paid no attention to the young and sang repeatedly. This bird was collected but proved to be a sorry specimen, being in moult. Only two tail feathers remained.

199. *Dendroica palmarum palmarum* (Gmelin). **Palm Warbler.** A common and early migrant, preceded only by the Myrtle Warbler. It is the only one of the warblers that frequents open fields as well as trees and shrubbery. In habits and appearance it seems to be a connecting link between the Water-Thrushes and the other warblers. It arrives April 20 to 30, the average date being April 25; the earliest, April 14, 1916 (Betts). One was seen in my yard March 28, 1920, and it is unfortunate the bird could not be taken to establish an exceptional record. The average date of departure is May 19; the latest, May 27, 1917. The fall migration is very erratic. The first migrants appear Sept. 12 to 30, the average date being Sept. 20; the earliest, Sept 6, 1919. The migration ends on the average Oct. 8; the latest, Oct. 12, (1913 and 1924).

200. *Seiurus aurocapillus* (Linnaeus). **Oven-bird.** The Oven-bird is a common migrant and summer resident. It is essentially a ground feeder, walking about like a fowl. In appearance it resembles a thrush. The average date of arrival is May 8; the earliest, May 2, 1913. The last migrants pass through the end of September, occasionally as late as the first week in October. The average date is Sept. 27; the latest, Oct. 10, 1929. Betts found a nest with eggs June 2.

201. *Seiurus noveboracensis noveboracensis* (Gmelin). **Water-Thrush.** A common migrant arriving early in May, sometimes at the end of April. The average date is May 4; the earliest, April 29, 1922. The average date of departure is May 22; the latest, May 29, 1927. The fall migration begins the end of August, the average date of arrival being Aug. 29; the earliest, Aug. 25, (3 years). The average date of departure is Sept. 21; the latest, Oct. 4, 1930.

202. *Seiurus noveboracensis notabilis* Ridgway. **Grinnell's Water-Thrush.** This western form of the Water-Thrush is fairly common during migration, though less so than the preceding species. Under favorable circumstances it is possible to distinguish a typical specimen of Grinnell's Water-Thrush in the field. Obviously, however, records can be based only on properly identified specimens, especially since there are many intermediates that require the opinion of experts. The color of the back has greater diagnostic value than the color of the under parts, or size of the bill. Mr. Warner Taylor took two May 18, 1921,[59] and one May 12, 1922.[60] Mr. John Main has a specimen that he took May 10, 1927. The extreme dates on which I have taken it in fall are Sept. 6 (1913) and Sept. 29 (1929).

203. *Seiurus motacilla* (Vieillot). **Louisiana Water-Thrush.** This warbler is a fairly common summer resident along the Mississippi River and up the Wisconsin River to Devil's Lake.[61] It is an uncommon migrant in the Madison region, but breeds regularly in small numbers in the northwestern part of the county in the river bottoms. This species arrives about two weeks ahead of the other Water-Thrushes. One seen at Madison on April 16, 1916, was undoubtedly a Louisiana. H. L. Stoddard collected one along the Wisconsin River April 17, 1921; and Mr. Warner Taylor one on April 30, 1921. Mr. John Main has a specimen collected near Madison May 5, 1929. Among summer specimens may be mentioned: a male taken by me in the Mazomanie bottoms on May 31, 1925; one taken by John Main in the same locality on June 13, 1926.

Stoddard found a nest with one egg in the Baraboo Bluffs on June 27, 1913. On June 13, 1926, I saw a pair in the Mazomanie bottoms feeding two young able to fly well. Nests with eggs should be sought about May 15.

204. *Oporornis formosus* (Wilson). **Kentucky Warbler.** Previous to the year 1924, this beautiful warbler was considered rare in the state. On June 9, 1913, Stoddard[62] found a pair along the Wisconsin River in Dane County and took the male. In June, 1924, I found this species common at Potosi, Grant

[59] Auk 39 (1922) 274.

[60] In Auk 40 (1923) 340, the date May 4 is a typographical error.

[61] Schorger, Auk 44 (1927) 238; Stoddard, Wilson Bull. 34 (1922) 78; Taylor, Auk 39 (1922) 274.

[62] Auk 34 (1917) 67.

County, and found two nests.[63] Taylor[64] collected one of three seen in the Mazomanie bottoms, May 25, 1925. It may be considered a regular summer resident in small numbers.

On June 11, 1927, I collected in the Mazomanie bottoms a female with her nest. The latter contained three eggs of the owner and two of the Cowbird. The eggs were heavily incubated in contrast with the nearly fresh eggs found at Potosi June 16 and 18, 1924. The nests, placed on the ground, were bulky structures, the base being composed of leaves and the lining of rootlets and hair.

205. *Oporornis agilis* (Wilson). **Connecticut Warbler.** A fairly common migrant, one of the latest of the warblers to arrive in spring. It is more numerous in spring than in fall. This species frequents tangles of briars and other low growths in woodlands where it may be located by its loud song. It appears about May 20 and departs the first week in June. The earliest date is May 18 (Taylor). I took one, June 6, 1920, the latest date on which it has been observed. On May 23, 1920, I saw twelve birds, which is unusual. Most of the autumn records are for the end of August and early September. The earliest date is Aug. 11, 1927. Warner Taylor[65] saw one Sept. 17, 1922. The latest date on which I have taken one is Sept. 7, 1918. On Oct. 18, 1927, I shot a Connecticut Warbler that afterwards flew a short distance and alighted on a limb. It seemed ready to fall so I tapped the limb with a stick. This proved to be a tactical error, for the bird volplaned for a hundred feet and alighted in some thick brush where it could not be found.

All breeding records for the state are questionable.

206. *Oporornis philadelphia* (Wilson). **Mourning Warbler.** This warbler is a common spring migrant, but the fall records are less numerous than for the Connecticut. It frequents the same type of country as the latter. The Mourning Warbler arrives somewhat earlier in spring, the average date being May 17; the earliest, May 11, 1916. The average date of departure is May 28; the latest, June 5, 1927. During a period of 17 years I have seen this warbler but three times in autumn: Aug. 14, 1921; Sept. 5, 1921 (collected); and Aug. 19, 1928.

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[63] Auk 44 (1927) 238.
[64] Auk 43 (1926) 382.
[65] Auk 40 (1923) 340.

Contrary to the statement of Kumlien and Hollister,[66] the breeding bird in northern Wisconsin is *O. philadelphia* and not *O. agilis*.[67]

207. *Geothlypis trichas trichas* (Linnaeus). **Maryland Yellow-throat.** An abundant migrant and summer resident. It frequents patches of weeds and brush, especially where there is wet ground. The invader of their territory is always scolded soundly. The average date of arrival is May 8; the earliest, May 2, 1926. It disappears in fall the end of September or the first week in October, the average date being Sept. 29; the latest, Oct. 12, 1929. There is one winter record. Mr. Clarence Jung saw one "in lively condition" on Dec. 20, 1920.

208. *Icteria virens virens* (Linnaeus). **Yellow-breasted Chat.** Its large size, extensive repertoire, and amazing aerial evolutions render the Chat outstanding among the warblers. The only place in the county where it may be relied upon to appear regularly every spring is the river bottoms near Mazomanie. Even here I have never been certain of the presence of more than one pair. The ubiquitous male will favor you with his notes, but is sometimes entirely unwilling to show himself. The earliest date for its appearance is May 7 (Taylor). My earliest records are May 23, 1925 and May 17, 1928.

Stoddard[68] collected one in the Mazomanie bottoms on June 13, 1913. Taylor[69] took one on May 17, 1925. I collected the male of a pair seen at Cross Plains on May 30, 1925.

There is no actual breeding record for the vicinity of Madison. Taylor[70] states that a pair, "probably nesting birds", were seen in mid-June, 1921, in the Lake Wingra region. On June 28, 1924, I found an adult bird in a tract of briars and second growth in the Wingra woods, but could not locate either a nest or young. On June 11, 1927, I took a female and her nest in the Mazomanie bottoms. The nest was placed four feet from the ground in a patch of blackberry bushes. It contained five eggs, including one of the Cowbird, that had been incubated three or four days. A nest found at Potosi, Grant County, June 9, 1925, contained one egg of the owner and one of the Cowbird.

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[66] "Birds of Wisconsin", (1903) p. 118.
[67] Schorger, Auk 42 (1925) 69.
[68] Auk 34 (1917) 67.
[69] Auk 43 (1926) 382.
[70] Auk 39 (1922) 274.

209. *Wilsonia pusilla pusilla* (Wilson). **Wilson's Warbler.** The Wilson's Warbler with its black cap, yellow waistcoat, and pert manner, is a common migrant. It should be looked for in thickets at the edge of swamps and in low woodland. It is erratic in its arrival that takes place from May 10 to 20. The average date for fifteen years is May 15; the earliest, May 6, 1916. The last migrants pass north the end of May, the latest date being June 3, 1917. It has been observed less often in fall than in spring. The main movement occurs at the end of August. The extreme dates for the fall migration are Aug. 22 (1920) and Sept. 9 (1918 and 1923).

210. *Wilsonia canadensis* (Linnaeus). **Canada Warbler.** This handsome warbler is a common migrant. It frequents the undergrowth and hence may be overlooked in autumn while the foliage is dense. This is a species that rarely sings on its migration. I have heard it on only two occasions and then at the end of May. It arrives from the 9th to 20th of May. The average date is May 16; the earliest, May 9 (1915 and 1927). It disappears the end of May, the average date being May 26; the latest, June 3, 1917. It is one of the earliest warblers to move south in autumn, the bulk of the species disappearing before September. The average date of arrival is Aug. 22; the earliest, Aug. 8, 1920. The migration is usually completed by Sept. 10, the latest date being Sept. 16, 1917.

211. *Setophaga ruticilla* (Linnaeus). **Redstart.** The Redstart is an abundant migrant and as a summer resident is second only to the Yellow Warbler in point of numbers. It prefers the low growths, and every suitable woodland contains one or more nesting pairs. The average date of arrival is May 7; the earliest, May 2 (1914 and 1923). It departs the end of September or early in October, the average date being Sept. 28; the latest, Oct. 7, 1924.

The neat, compact nests are placed two to eight feet from the ground. Construction begins about May 20. Full sets of fresh eggs have been found from June 6 to July 7. By June 18 most of the nests contain eggs, the usual number being four, five the exception. Young, able to fly, have been observed by June 21. This species is frequently host to the eggs of the Cowbird. I have seen a female feeding a young Cowbird as late as Aug. 4.

Family ICTERIDAE. Meadowlarks, Blackbirds, Orioles, etc.

212. *Dolichonyx oryzivorus* (Linnaeus). **Bobolink.** This fine song bird is an abundant summer resident. It arrives early in May, the average date being May 5; the earliest, April 30 (Taylor). The birds begin to flock the latter part of August at which time only a small percentage of the males give evidence of breeding plumage. At this season and until departure for the south, marshy ground and grain fields are frequented. In about one half of the years the fall migration is completed by the end of August. In other years a few are seen as late as Sept. 14 to 21. The latest date is Oct. 3, 1914, when a single bird was seen. Occasionally it remains in large numbers into September. On Sept. 6, 1915, by far the largest flock of Bobolinks that I have seen in the state was found at Fox Lake, Dodge County. This flock, numbering three to four thousand birds, was feeding in a field thickly covered with pigeon grass *(Setaria glauca)*.

Two nests of eggs were found May 30, 1927 by Mr. George French. I found a nest with five heavily incubated eggs June 16, 1914.

213. *Sturnella magna magna* (Linnaeus). **Meadowlark.** An abundant summer resident that occasionally winters, especially near springs. It arrives from March 9 to 20, the average date being March 14; the earliest, March 5, 1922. Previous to departure it collects in small flocks. The migration is usually completed by the end of October, though an occasional bird may be seen until the end of November.

Nests with eggs are usually found about the middle of May. The earliest date is May 1, 1921, when I flushed a bird from a set of six eggs. This nest was placed on a hillock in a marsh. The latest date is June 19, 1926, when Mr. George French found a nest with eggs.

214. *Sturnella neglecta* Audubon. **Western Meadowlark.** This western bird is now a common summer resident and continues to extend its range in the state. Kumlien and Hollister[71] state that it was found regularly in very late fall in Rock, Jefferson, and Dane Counties, but had not been observed in spring or summer. I first observed this species in the vicinity of Madi-

[71] "Birds of Wisconsin", (1903), p. 88.

son, April 13, 1916.[72] In the spring of 1917, several singing birds were observed and a male was taken April 29, 1917. Since that time it has gradually increased to the extent of being common.[73] It is possible that this form arrives at the same time as the Meadowlark, since in recent years, due to increase in the number of birds and hence in observations, the dates have become closer. In the period 1916-1920 the first arrivals were noted April 10 to 14; while from 1925-1928, the first birds were found March 18 to 21. The song of the Western Meadowlark is entirely different from that of the eastern bird and is decidedly superior to it. The alarm note is a characteristic cluck. I have heard it singing as late as Oct. 22 (1921).

Near the Wisconsin River, Stoddard found a nest with three eggs April 28, and another with four eggs May 11, 1921, "both in long dead grass in the sand prairie."

215. *Xanthocephalus xanthocephalus* (Bonaparte). **Yellow-headed Blackbird.** A common summer resident, breeding in marshes, lakes and streams, where there are beds of cattails. It seems incongruous for so handsome a bird as the male to have a squeaky, unmusical song. In the middle of the past century this species was a desideratum for the cabinets of eastern collectors, and many skins were supplied from the Koshkonong region by Thure Kumlien. When Thomas Brewer, who acted as agent for the disposal of the skins, wrote that the price had fallen, Kumlien replied: "I am glad to get fifty cents a piece for yellow-headed blackbird skins, and I wish I could sell many for that price. It is easier for me to kill and skin a bird than it is to go out and work hard for fifty cents a day for a farmer."[74]

This species arrives from April 27 to May 11, the average date being May 4; the earliest, April 24, 1920. By July 15, the males have lost nearly all of their gaudy feathers, and have taken on the sober winter plumage. The only note uttered at this season is *"tur-r-rt"* or *"twur-r-rt"*. From this time until departure it associates with Redwings and Cowbirds in the fields and marshes. For a Blackbird, the fall departure is very

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[72] Auk 34 (1917) 219.

[73] *Cf.* Taylor, Auk 39 (1922) 273; Stoddard, Wilson Bull. 34 (1922) 77.

[74] P. V. Lawson, "Thure Kumlien," Wis. Acad. 20 (1921) 669; *cf.* Mrs. Angie Kumlien Main, "Yellow-headed Blackbird at Lake Koshkonong and Vicinity," *ibid.* 23 (1927) 631.

early, as practically all have left before September. The average date of departure is Aug. 19. An exceptionally late date is Oct. 12, 1918 (Clarence Jung).

The bulky nest is always placed over water and is suspended from reeds or cattails. Completed nests have been found by May 19; and eggs from May 30 to June 22. The eggs must be occasionally deposited much earlier, since on May 30, 1921, a nest with one egg and two callow young was found at Fox Lake, Dodge County.

216. *Agelaius phoeniceus arctoglegus* (Oberholser). **Giant Redwing.** The breeding bird has been referred to this form by Dr. H. C. Oberholser.[75] It is doubtful if the eastern bird *(Agelaius p. phoenicus)* occurs in the state. The Redwing is an abundant migrant and summer resident. The males arrive from March 5 to 20, usually before the middle of the month. The average date is March 11; the earliest, March 3, 1913 (Betts). The females arrive about a month later. In fall flocks of thousands are found in the cornfields and marshes. Immense roosts are formed at this season in favorite marshes, such as Lake Wingra, where towards evening the birds arrive in a steady stream. The last birds are seen from Nov. 1 to 25, the average date being Nov. 12. Freezing of the marshes is the signal for departure. Individuals to small flocks winter rather frequently.

Despite the early arrival of the Redwing, nest building does not begin until May. Eggs have been found from May 12 to June 19, the majority the last two weeks in May. A nest found May 17 contained two eggs and a callow young, indicating that eggs have been laid at least by May 7. Nesting colonies are frequently destroyed by skunks. Large flocks of old and young birds form by July 1.

217. *Icterus spurius* (Linnaeus). **Orchard Oriole.** The Orchard Oriole is a summer resident in small numbers. It is not sufficiently numerous to permit fixing more than tentative dates for the migrations. It arrives in spring from May 12 (1915) to 20, the average date being May 17. Data on the fall migration are wholly wanting. The latest date on which it has been observed is July 19, 1913.

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[75] Schorger, Auk 45 (1928) 106.

A nest found June 28, 1927, was in an inaccessable place in the top of a large oak standing in the yard of the Williamson farm, Lake Waubesa. This Oriole is local in distribution, returning to the same places year after year.

218. *Icterus galbula* (Linnaeus). **Baltimore Oriole.** A common summer resident, arriving May 1 to 12. The average date is May 5; the earliest, April 26, 1925. It departs the end of August or early in September. The average date for 17 years is Aug. 31; the latest, Sept. 9, 1916. In this latitude nests with eggs are usually found during the first week in June. Young able to fly have been seen by June 26.

219. *Euphagus carolinus* (Müller). **Rusty Blackbird.** The Rusty Blackbird is an abundant migrant that generally associates with Redwings. It arrives later than the Redwings and is rather irregular in its movements. Though usually arriving in March, in some years it has not been noted until April. The average date of arrival is March 22; the earliest, March 12 (1916 and 1922). It departs the latter part of April, occasionally not until May. The average date is April 20; the latest, May 8, 1920. It appears in autumn in October, infrequently in September. The earliest date is Sept. 13, 1925, when a single bird was noted. Betts observed it Sept. 28, 1913. The average date of arrival is Oct. 10. Departure takes place in November and is guided by the freezing of the marshes. The latest date on which a flock has been seen is Nov. 26, 1925. Single birds sometimes winter.

220. *Euphagus cyanocephalus* (Wagler). **Brewer's Black-Bird.** There are few occurrences of this species for the county. On June 9, 1926, Mr. John Main[76] discovered a pair nesting in the Wingra marsh. The nest, placed on the ground, contained three young. These were sufficiently developed to leave the nest the following day. The adult male was taken by Mr. Main, and is now in his possession. Four pairs were found by him in the same locality May 13, 1930.[77]

This species has always been considered rare in the state. Recently, it has been reported as a common summer resident at Hayward, Sawyer County.[78]

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[76] Auk 43 (1926) 548.
[77] Auk 47 (1930) 579.
[78] G. Eifrig, Wilson Bull. 40 (1928) 216.

221. *Quiscalus quiscula aeneus* Ridgway. **Bronzed Grackle.** This splendid blackbird is a common summer resident, less numerous however, even in migrations than the Redwing or Rusty. It arrives March 11 to 25, the average date being March 19; the earliest, March 10 (Taylor). In July, August, and September, troops of Grackles walk sedately about the lawns searching for insects. During the middle of October, preparatory to leaving, it collects in flocks that sometimes number one to two thousand birds. The average date of departure is Oct. 24; the latest, Nov. 7, 1920.

The nest is usually placed in evergreens, occasionally in holes. Work on the foundation has been noted by April 6, though finished and incomplete nests exist at the end of the month. Full sets of eggs have been found from May 5 to 15. Young able to fly have been seen by June 6.

222. *Molothrus ater ater* (Boddaert). **Cowbird.** An abundant summer resident, arriving from March 15 to April 10. The average date is March 27; the earliest, March 12, 1916 (Betts). In summer and autumn the Cowbirds collect in small flocks or associate with Redwings. A flock of 200 cowbirds seen on Sept. 8, 1923 is the largest that I have observed. The fall migration is early, since as a rule nearly all have departed by Sept. 1. Individuals, usually young birds, probably hatched in late summer, occasionally remain until October. The latest date is Oct. 7, 1928. It winters rarely. One was seen by Mr. Clarence Jung on Dec. 20, 1920.

The Cowbird is unique in that its eggs are always deposited in the nests of other birds. Friedmann[79] lists 195 foster parents of this species, of which only 80 are commonly victimized. Eggs are deposited in the empty nests or after the owner has begun to lay. I have seen an Indigo Bunting incubating three eggs of the Cowbird and none of her own. A nest of a Willow Thrush found in Bayfield County contained five eggs of the Cowbird and two of the owner. The earliest date on which an egg of the Cowbird has been found is May 1, 1921, in the nest of a Song Sparrow; the latest, July 18, 1925, in the nest of a Field Sparrow.

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[79] "The Cowbirds", Springfield, (1929), p. 198.

Family THRAUPIDAE. Tanagers.

223. *Piranga erythromelas* Vieillot. **Scarlet Tanager.** The Scarlet Tanager is a common migrant and summer resident. Early in May, before the trees have leaved, the brilliantly colored male is a conspicuous bird. The first arrivals are occasionally seen upon the ground. During the nesting season, the birds confine themselves to the treetops and easily escape detection when silent. The characteristic note is *"dip-tur-r-r"*. The song resembles that of the Robin but has a nasal quality. It arrives on the average on May 9, the earliest date being May 2, 1913. After the breeding season, the male changes his plumage to the green and yellow of the female. I have seen the male with yellow feathers in the breast on July 24. In one case at least, the moult was incomplete on Sept. 17. This species usually disappears the latter part of September, the average date being Sept. 22; the latest, Oct. 4, 1919.

A nest found June 16 was placed on a lateral branch of a white oak. It contained three eggs of the Cowbird and two of the owner.

Family FRINGILLIDAE. Finches, Sparrows, etc.

224. *Richmondena cardinalis cardinalis* (Linnaeus). **Cardinal.** The Cardinal is an interesting example of a bird of the Carolinian fauna that is gradually extending its range northward. Kumlien and Hollister listed it as rare in 1903. Its increase in the upper Mississippi valley has been described by Miss Althea R. Sherman.[80] While at Potosi, Grant County, in 1924, I was informed that the Cardinal was almost unknown there previous to 1900. I saw my first Cardinal in the vicinity of Madison on Dec. 25, 1916. Since that time it has become a common permanent resident. It adapts itself readily to towns and is more common in Madison and its suburbs than in the surrounding country. The valleys of the Mississippi and Wisconsin Rivers are the most thickly populated sections and furnish the pioneers of outlying territory.

Nests with eggs have been found from June 2 to 7. A nest found at Cross Plains on June 8 contained four callow young.

[80] Wilson Bull. 25 (1913) 150.

225. *Hedymeles ludoviciana* (Linnaeus). **Rose-breasted Grosbeak.** This bird is a common summer resident, preferring roadside thickets and second growth. It arrives early in May, the average date being May 7; the earliest, May 1, 1914. The finding of a singing bird in female plumage on July 18 indicates that a male had already moulted. It departs in September, the average date being Sept. 21; the latest, Sept. 26, 1920.

Full sets of eggs have been found from May 30 to June 19. In one case the male was covering the eggs.

226. *Passerina cyanea* (Linnaeus). **Indigo Bunting.** A common summer resident along brushy roadsides and the edge of woods. The drab female prefers the retirement afforded by thick bushes while the male chooses to sing from an elevated perch. It arrives from May 3 to 20, the average date being May 11; the earliest, April 29, 1916. Departure takes place the latter part of September, occasionally early in October. The average date is Sept. 23; the latest, Oct. 12, 1930.

Eggs have been found from June 7 to July 26; in most cases, during the second week in June. On Aug. 16, 1914, a nest was found containing three half-fledged young. Two broods are reared. June and early July nests are rarely free from the eggs of the Cowbird, while the later ones are frequently so.

227. *Spiza americana* (Gmelin). **Dickcissel.** This bunting is noted throughout its changeable range for great fluctuations in numbers over a period of years. Hollister[81] e.g., mentions that a pair, the first seen in several years, summered at Delavan in 1897; while in 1901 it was "one of the most common of roadside birds".[82] The Dickcissel has been common to abundant in sections of Dane County during most of the past seventeen years. It was uncommon in the period 1915-1920, and again in 1924. The favorite habitat is a clover field. There the males will be heard singing from the day of their arrival until their departure. It is a late migrant, arriving the end of May or early in June. The average date of arrival is May 29; the earliest, May 21 (Taylor). One collected Aug. 2, 1913, was in moult. They depart the end of July or early in August, the latest date being Aug. 6, 1913. Kumlien and Hollister[83] state that they

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[81] Wilson Bull. 9, No. 1 (1897) 4.
[82] Kumlien and Hollister, "Birds of Wisconsin," (1903) p. 103.
[83] *l. c.*, p. 103.

found young, only recently from the nest, in September. This must be considered exceptional. Gross,[84] who made a special study of the Dickcissel in central Illinois, found that nearly all were gone by Sept. 10-15. The average date of arrival is given as May 3, or 26 days earlier than in Dane County. Nehrling[85] states that the Dickcissel does not reach eastern Wisconsin before May 15 and commences to move south early in September.

228. *Passer domesticus* (Linnaeus). **English Sparrow.** This foreign species was introduced into Wisconsin at Fort Howard and Sheboygan in 1875.[86] It has long since become an abundant permanent resident. A flock occupies a restricted area and if the birds are killed, some time is required to fill the void. In fall, especially, large roosts are formed in the vines on churches and in certain trees. During the cold of winter the birds usually roost singly wherever a protected nook can be found. It is a very clever bird, quickly sensing danger, and will seldom enter a trap twice. Many of its habits are undesirable, but the devotion shown its young commands respect. In protecting my bird houses, I tried the experiment of shooting only the females. The male would obtain another mate in the course of a few hours or a day, and the attempt at nesting would not be abandoned until three or more females had been dispatched. On Feb. 26, 1913, I observed a female carrying nesting material, though snow covered the ground to a depth of seven inches.

229. *Hesperiphona vespertina vespertina* (Cooper). **Evening Grosbeak.** Like many of the boreal birds, the Evening Grosbeak is of erratic occurrence. Usually it does not arrive until December or January; however, I saw two on Oct. 15, 1916 near Madison, and collected a lone female in Iowa County, just beyond the Dane County line, on Oct. 21, 1927. It was common at Madison from Jan. 7 to May 7, 1917, and from Jan. 2 to April 10, 1919. The favorite food is the seed of the box elder *(Acer negundo)*.

230. *Carpodacus purpureus purpureus* (Gmelin). **Purple Finch.** A very common migrant in spring and fall, and a frequent winter resident. Its movements are the most erratic of

[84] Auk 38 (1921) 11.
[85] "Our Native Birds", 2 (1896) 229.
[86] Barrows, "The English Sparrow in America." Washington, (1889) p. 19.

all our regular migrants. The spring arrival is greatly complicated by the winter residents, but it appears to take place from March 15 to April 15. It is most numerous the last week in April and the first week in May. During this period the aspens are in blossom and form a special attraction for the Purple Finch. Departure takes place from May 3 to 14, the latest date being May 18, 1919, when fifteen were seen. In autumn, the first birds will appear at any time between the end of August and the middle of October. The earliest date is Aug. 20, 1921. It is most common from Sept. 20 to Oct. 20.

231. *Pinicola enucleator leucura* (Müller). **Pine Grosbeak.** This grosbeak is an infrequent winter visitor. The earliest and latest dates for its occurrence were obtained by Mr. Clarence Jung who found them along the University Drive from Nov. 2, 1918 to the end of Feb. 1919. I saw a flock of six on Jan. 1. and another of eight on Feb. 22, 1922.[87] Some of the birds, while feeding in European larches, dropped to the ground to collect detached seeds. The following data have been furnished by Warner Taylor: four seen on Dec. 30, 1918; three on Jan. 19, and three on Jan. 23, 1919; four on Jan. 17, and nine on Jan. 26, 1922. The next date for its appearance is Dec. 26, 1929, when two were seen by John Main and Warner Taylor.

232. *Acanthis linaria linaria* (Linnaeus). **Redpoll.** This hardy little bird is an irregular winter visitor from the north. During some winters it does not appear at all; again it is present in great numbers. Flocks of 100 to 500 birds are not uncommon. On March 7, 1926, there was a strong wind accompanied by snow. A flock of 1500 was found feeding on ragweed in a field. At intervals all the birds would leave the ground in an immense swirl. They arrive from Nov. 5 to Jan. 1, usually in November or early in December. The earliest date is Oct. 28, 1916. Departure for the north takes place from March 5 to March 21 (1926).

233. *Spinus tristis tristis* (Linnaeus). **Goldfinch.** The "Wild Canary" is a common permanent resident, though much less numerous in winter.

The neatly constructed nest is usually placed in a bush at a height of 3 to 10 feet from the ground. Completed nests have

[87] Auk 39 (1922) 574.

been found by July 11; eggs, from July 13 to Aug. 25, the majority between July 31 and August 12. An egg is deposited daily apparently, since a nest empty on July 31 contained five eggs on Aug. 7. Young have been found in the nest as late as Sept. 12 (1925). None of the nests found contained eggs of the Cowbird.

234. *Spinus pinus pinus* (Wilson). **Pine Siskin.** This small boreal finch is a common migrant, frequently remaining throughout the winter. It is erratic both as to occurrence and numbers. During five of the past seventeen years, it was not seen. Though usually found only in small flocks, numbering less than twenty-five, I found a flock of 250 on April 14, 1923.[88]

The earliest date of its appearance in autumn is Sept. 12, 1925. During other years, the first birds were seen from Sept. 28 to Nov. 25. There is a well defined spring migration from April 20 to the middle of May. Departure for the north frequently does not take place until the third week in May, the average date being May 15; the latest, May 23, 1920.

It has been seen feeding on ragweed, and the cones of arbor vitae and European larch, but the favorite food in fall and winter is the seed of the white birch. The snow is frequently carpeted with fragments from the strobiles.

235. *Loxia curvirostra minor* (Brehm). **Crossbill.** The Crossbill is a very irregular visitor that appears about one winter in three. The earliest occurrence is Sept. 12, 1925, when a lone bird was found in a flock of Pine Siskins; otherwise, it has not been noted before January or February. It was common near Madison from April 5 to 14, 1923, the latest date on which it has been noted in spring.[89] As a matter of record, one was taken Feb. 21, 1914, and two, Jan. 16, 1926. This species has been frequently found feeding upon the ground. A flock was once observed feeding on the seeds of ragweed projecting above the snow. A game of leap-frog seemed to be in progress, as the birds in the rear were constantly flying to the head of the feeding column.

Kumlien and Hollister[90] state that it nested "formerly as

[88] Auk 41 (1924) 169.
[89] Schorger, Auk 41 (1924) 169.
[90] "Birds of Wisconsin," (1903) p. 92.

far south as Dane County. Young just able to fly were procured in a cemetery at Albion in August, 1869."

236. *Loxia leucoptera* Gmelin. **White-winged Crossbill.** This species is a rare winter visitor. No specimens have been taken in the county, but Mr. Warner Taylor found them on numerous occasions during the winter of 1919-1920 as follows: 40 on Dec. 26 and 27, 1919; 15 on Jan. 30; 3 on Feb. 10; 1 on Feb. 19; 2 on Feb. 22; 25 on Feb. 25; and 2 on March 27, 1920. There are no other records.

237. *Pipilo erythrophthalmus erythrophthalmus* (Linnaeus). **Towhee.** A common summer resident in second growth and open woodland containing tangles of vines and bushes. The males come ahead of the females. They arrive from April 3 to 23, usually not before the middle of the month. The average date is April 13; the earliest, March 30, 1920. It departs the end of October or early in November, the average date being Oct. 24; the latest, Nov. 12, 1929 (Paul Errington).

The nest is usually concealed at the base of a bush, stump, or sapling. Nests with eggs have been found from May 14 to 24. Young able to fly have been seen by June 14. This species seldom escapes being host to the Cowbird. Two or three eggs of the latter to one of the owner is a frequent ratio.

238. *Passerculus sandwichensis savanna* (Wilson). **Savannah Sparrow.** This sparrow is a common summer resident in grassland and dry marshes. After the breeding season it assembles in small flocks in the vicinity of water, and up to the time of departure is found about wet marshes, ponds, and lakes. It arrives from the end of March to April 22, the average date being April 10. The earliest date is March 19, 1921. I took a female March 23, 1913. It departs on the average October 15, the latest date being Oct. 25, 1924.

239. *Ammodramus savannarum australis* Maynard. **Grasshopper Sparrow.** A common summer resident, returning regularly to undisturbed fallow fields. From his perch on a weed stalk the male utters a weak, insect-like song. It seldom arrives before May, the average date being May 8; the earliest, April 25, 1925. The latest date on which I have heard it singing is July 28. Data on the fall migration are almost wholly want-

ing. Nehrling[91] states that it leaves Wisconsin in September.

240. *Passerherbulus henslowi henslowi* (Audubon). **Henslow's Sparrow.** Henslow's Sparrow is a common migrant and summer resident. During the breeding season it is found mainly on marshy land and is very local in distribution. Confining its activities largely to the ground, where it runs like a mouse, it is a difficult bird to find without flushing. In spring the males sing frequently in full view from a bush or old weed. The song is a very unmusical '*tsilk-tsilk-tsilk*". I have also found it singing frequently from weeds in high, fallow fields during the migration in early May. The flight of this species is irregular and fairly rapid. I have surprised it while sitting in a bush. On such occasions it is very uneasy and seems unable to determine whether to stay or fly.

It arrives the end of April or the first of May, the average date being April 25. The earliest date is April 18, 1915; in addition I took one April 23, 1927. Mr. John Main collected one on the Sauk prairie, Sauk County, on the exceptionally early date of April 7, 1929. In the years 1913-1915, previous to draining, this sparrow was a common summer resident in the southern end of the University Bay marsh. The ground was wet, but there was almost no standing water. Here the males were in song as late as Aug. 3. It disappears in autumn from Sept. 24 (1927) to Oct. 3 (1914). One was collected on the latter date. An unusually late occurrence is Nov. 14, 1914. While hunting, I crossed a well grazed pasture on high ground, and glancing down, saw a Henslow's Sparrow about three feet distant. The bird flew normally when flushed.

I have never been able to find a nest of this species. At "Hog Island," Lake Waubesa, on June 20, 1915, I caught a young bird that, while unable to fly, was exceedingly nimble afoot.

241. *Passerherbulus lecontei* (Audubon). **Leconte's Sparrow.** Search for the sharptailed sparrows is so fascinating that it may easily become a mania. Of all the members of the group, Leconte's Sparrow is the most baffling. Regardless of effort, there have been years when I could not find this sparrow at all, while three is the maximum number that I have found in one day. I have had the best success in finding this bird by walking rapidly back and forth through the dead, brown grass in the

[91] "Our Native Birds," 2 (1896) 87.

dry sections of a marsh. Its flight normally is slow, straight, and fluttering like that of the Short-billed Marsh Wren. It is very difficult to flush a second or third time, even though it alights but a short distance away, and you repair immediately to the spot. The only safe record is the collected bird. Obviously, no fixed rules apply to bird behavior, but I have seen this bird at rest on only two occasions: one flushed from the grass alighted on the branch of a willow shrub where it remained a few seconds before dropping to the ground; early in the morning of May 4, 1928, I collected one that alighted on the lower branch of a tree after flushing from a muddy area, almost devoid of cover, beside a pond. I have never heard a note from this species; however, Taylor[92] has recorded the finding of a singing male April 16, 1916, and again on May 10, 1919.

Kumlien and Hollister[93] gave numerous fall records for this species, but none for spring. Subsequently, two spring records were obtained at La Crosse, May 11 and 13, 1907; while one was found dead at Mayville, March 29, 1910.[94] Specimens have been taken in Dane County as follows: one taken on Oct. 12, 1913[95], one on April 11, and two on April 15, 1914;[96] and one May 4, 1928, by the writer; one on April 12, 1914, by Norman DeWitt Betts; and one on Oct. 9, 1922, by Warner Taylor.[97] It arrives about the middle of April and has been found in Dane County from April 11 to May 16. The fall migration takes place in October, inclusive dates being Oct. 9 to 19.

242. *Ammospiza nelsoni nelsoni* (Allen). **Nelson's Sparrow.** This, the handsomest of our sparrows, was discovered by E. W. Nelson, in 1874, in the Calumet Marsh near Chicago. It is quite remarkable that this species has not been taken in Wisconsin in spring, in view of the fact that it has been found "exceedingly abundant about Lake Koshkonong in September and early October."[98] Dwight[99] stated that it was found sparingly during the breeding season in Wisconsin. An inquiry resulted in the following reply from Dr. Dwight under date of May 22,

[92] Auk 37 (1920) 299.
[93] "Birds of Wisconsin", (1903) p. 96.
[94] I. N. Mitchell, Bull. Wis. Hist. Soc. 8 (1910) 161.
[95] Auk 31 (1914) 256.
[96] Auk 32 (1915) 101.
[97] Auk 40 (1923) 339.
[98] Kumlien and Hollister, *l. c.,* p. 97.
[99] Auk 13 (1896) 275.

1926: "—— I concluded that specimens I have in full juvenal plumage belonged to local broods. These specimens taken early in Sept. (10th) at Lake Koshkonong doubtless misled me in my youthful enthusiasm."[100]

Nelson's Sparrow is usually found in autumn in wet marshes. I took my first specimen Sept. 24, 1921 in a low, wet pasture that had been cropped so short that there was no cover.[101] This bird alternately ran and stopped, and did not appear alarmed. In comparison with Leconte's Sparrow, it is easy to flush. As a rule it does not drop to the ground, but alights in the reeds or rushes where it twitches about, frequently in full view. I once pursued a Nelson's Sparrow a distance of 200 yards, and after several flushings, it alighted on the top of some marsh grass. Its flight is irregular and quite rapid.

Previous to the fall of 1926, I was never able to find this species regularly. On Sept 25, 1926, I found seven in a marsh near the Wisconsin River and found them again in the same locality in fall in 1927, 1928, and 1929. It has never been abundant. Taylor[102] collected three from a flock of a dozen Sept. 30, 1922. The largest number that I have seen in one day was twenty, on Sept. 24, 1927. In addition to the above collections, I have taken specimens as follows: one on Sept. 30, 1923; two on Sept. 25, 1926; three on Sept. 24, 1927; and two on Sept. 16, 1928. On Oct. 4, 1929, while searching for a Wilson's Snipe that I had shot, I found a dead Nelson's Sparrow concealed in the marsh grass on a hillock. This bird was upright on a bare spot of ground and had its back arched greatly. It had been dead but a few hours, since the eyes had not sunk. On preparing the skin, the bird was found to be greatly emaciated; there was no external injury. It had been observed in fall from

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[100] I have been unable to find a record of a capture in spring in Wisconsin. It has been reported as seen in Oconto County on June 17, 1897, by Mr. A. J. Schoenebeck (Birds of Oconto County, 1902, p. 36). All the reports in the Wisconsin Arbor and Bird Day Annuals for 1911, 1912, and 1913, are questionable. As for Illinois, Nelson (Bull. Essex Institute 8 (1876) 107) states that he saw several at Calumet Lake on June 12, 1875; and Woodruff, (Birds of the Chicago Area, 1907, p. 138) that he took the nest and eggs in the same locality. I am indebted to Dr. H. C. Oberholser for searching the files of the Biological Survey. He located several dates in the migration reports of observers, but was unable to find that a specimen had been taken. The only definite record that I have found is that by C. W. G. Eifrig (Auk 40 (1923) 132) who took a male near Chicago May 27, 1922.

[101] Auk 39 (1922) 574.

[102] Auk 40 (1923) 339; *cf. ibid.* 43 (1926) 381.

Sept. 16 to Oct. 14 (Taylor); the period of greatest numbers is the last week in September.

243. *Pooecetes gramineus gramineus* (Gmelin). **Vesper Sparrow.** This sparrow is a common summer resident. It frequents fields and roadsides, and in its wavering flight the white outer tail feathers are conspicuous. It arrives from March 23 to April 10, the average date being April 2; the earliest, March 19, 1921. It departs the latter half of October, the average date being Oct. 22; the latest, Nov. 2, 1924.

244. *Chondestes grammacus grammacus* (Say). **Lark Sparrow.** This fine sparrow, accustomed from time immemorial to the unbroken prairie, has adapted itself reluctantly, when at all, to cultivated ground. In Wisconsin it is confined largely to waste, sandy areas too poor for the plow. Beginning at Boscobel, it occupies the sand flats of the Wisconsin River valley to the center of the state. Here, amidst sparse vegetation, the males from jack pine or stunted oak sing the sweetest of all our sparrow songs—a succession of trills and chants. Near Gotham, Richland County, I found it to be an abundant summer resident. In Dane County, it is confined to the sandy areas of the Mazomanie bottoms.[103] It reaches southern Wisconsin about April 20 and departs in September. The latest that I have seen one is Sept. 26 (1920), and this happens to be the only one that I have seen in the vicinity of Madison. A male taken at Gotham June 11, 1925, was in moult.

245. *Passerella iliaca iliaca* (Merrem). **Fox Sparrow.** An abundant migrant, frequently arriving before the snow has disappeared. Late blizzards do not dampen its spirit and it continues to sing merrily. During the migrations it is found along bushy roadsides, in thickets and the edge of woods. It scratches industriously amongst the litter on the ground in its search for seeds, and when the leaves are dry the noise produced by several birds is certain to attract attention. This species arrives from March 17 to April 1, the average date being March 24; the earliest, March 12, 1927. It usually departs the third week in April, the average date being April 23. Two late dates are May 10, 1924 and May 8, 1927. Fall arrival varies

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[103] Stoddard, Wilson Bull. 34 (1922) 77; Taylor, Auk 39 (1922) 273; 40 (1923) 339.

from Sept. 20 to Oct. 10, the average date being Oct. 1; the earliest, Sept. 12, 1925. It departs from Oct. 28 to Nov. 12, the average date being Nov. 5; the latest, Nov. 15, 1919.

246. *Junco hyemalis hyemalis* (Linnaeus). **Slate-colored Junco.** The Junco is an abundant migrant, and a common and regular winter resident. In winter it is confined largely to the vicinity of conifers. At this season it associates freely with Tree Sparrows. It appears from the north from Sept. 19 to Oct. 4, the average date being Sept. 27; the earliest, Sept. 14, 1919. It is most numerous in October, large numbers occasionally remaining through November. About the middle of March there is a noticeable increase in numbers, the heighth of the migration being reached the first week in April. The migration is practically completed the last week in April, though stragglers continue to pass through up to the middle of May. The average date of departure is May 2; the latest, May 18, 1917.

247. *Spizella monticola monticola* (Gmelin). **Tree Sparrows.** This is another abundant migrant and common winter resident. It appears happy in the coldest weather, sounding its tinkling notes as it feeds on the ragweed. It arrives in fall between Oct. 7 and 24, the average date being Oct. 16; the earliest, Oct. 3, 1923, when 200 were seen. It is most abundant in November. By early December usually only wintering birds remain. The birds wintering to the south pass through again in March and early April. The migration is completed from April 12 to 29 (1928), the average date being April 20.

248. *Spizella passerina passerina* (Bechstein). **Chipping Sparrow.** The Chipping Sparrow is only a fairly common summer resident. It elects to nest in the vicinity of dwellings, a decided preference being shown for conifers. It appears from April 8 to 22, the average date being April 18. Nearly all have departed before the middle of September; in fact, the latest date on which it has been noted is Sept. 19, 1915 (Betts). There is one winter record. Mr. Clarence Jung informs me that he saw one in Tenney Park on Jan. 25, 1920.

Nests with eggs have been found up to June 23. A young bird barely able to fly was seen being fed on Sept. 6, 1920.

249. *Spizella pallida* (Swainson). **Clay-colored Sparrow.** This unobtrusive little sparrow is a regular migrant in small

numbers and an irregular summer resident. It breeds abundantly in some of the northern counties, hence it should be more common as a migrant. To the northward it is found in dry, gravelly, waste spaces overgrown with sweet fern, hazel and similar low growth. The male perched on a bush sings repeatedly with elevated head. The song is a weak, unmusical "*ak-ak-ak-ak*". It appears early in May, the average date being May 6; the earliest, May 2, 1926. The fall migration begins the latter part of September and extends into October. The extreme dates are Sept. 20, 1930 and Oct. 6, 1929. The following specimens have been taken: one on May 30 and one on June 27, 1920; one on May 2, 1926; one on May 21, 1927; and one on May 12, 1929 (Schorger); two on May 8, 1919; one on Oct. 2, 1922; and one on May 13, 1925 (Taylor).[104] It was found nesting near Madison in 1919 and 1921 by Mr. Warner Taylor.[105] It bred here also in 1920.[106] The eggs resemble those of the Chipping Sparrow. The nest is placed on or close to the ground or, at a height of two to four feet, in bushes or small conifers. The nest found by Mr. Taylor on May 30, 1919, contained three eggs and was placed on the ground at the foot of a bush. I have examined numerous nests in northern Wisconsin. Here they were located in bushes and small conifers.

250. *Spizella pusilla pusilla* (Wilson). **Field Sparrow.** This lovable sparrow is a common summer resident along roadsides and in bushy fields. It arrives from March 20 (1921) to April 12, the average date being March 30. It departs in October, the average date being Oct. 13; the latest, Oct. 26, 1930.

The nest is placed on the ground in a tuft of grass or in a bush. Two broods are reared. Full sets of eggs have been found from May 18 to July 18.

251. *Zonotrichia querula* (Nuttall). **Harris's Sparrow.** Harris's Sparrow is sufficiently uncommon that a sight of it is always a source of satisfaction. It usually occurs singly in flocks of White-throated Sparrows. The status of this species in Wisconsin and adjacent states has been reviewed by Cahn[107] and by Swenk and Stevens.[108] The relative abundance of Har-

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[104] Auk 37 (1920) 299; 40 (1923) 339; 43 (1926) 381.
[105] Auk 37 (1920) 300; 39 (1922) 274.
[106] Schorger, Auk 43 (1926) 557.
[107] Bull. Wis. Natural History Soc. 13 (1915) 102.
[108] Wilson Bull. 41 (1929) 129.

ris's Sparrow and the White-throated Sparrow is of interest. Prof. George Wagner has kindly furnished the following data: during the period February, 1925, to Jan. 1, 1930, he and his students banded 4 Harris's Sparrows and 1900 White-throated Sparrows, a ratio of 1 to 475.

There are the following records for Dane County:

No.	*Date*	*Observer*
1 seen	May 10, 1914	R. E. Kremers[109]
3 seen	May 12, 1914	A. R. Cahn[109]
1 seen	May 11, 1916	A. W. Schorger[110]
1 seen	May 21, 1921	Warner Taylor[111]
1 banded	May 15, 1926	W. B. Grange
1 collected	May 16, 1926	A. W. Schorger[112]
1 banded	May 11, 1928	D. F. Hansen
1 banded	May 12, 1929	Wayne Dancer
1 seen	Oct. 21, 1917	A. W. Schorger[112]
1 seen	Sept. 22, 1923	A. W. Schorger
1 seen	Oct. 3 1923	Warner Taylor[113]
1 banded	Oct. 13, 1926	John Gundlach
1 collected	Oct. 16, 1927	A. W. Schorger
1 seen	Sept. 29, 1929	A. W. Schorger
1 collected	Oct. 2, 1929	A. W. Schorger
2 seen	Oct. 12, 1930	A. W. Schorger

It will be observed that all the spring records fall between May 10 and 21, a period of only twelve days. The fall migration is much longer, ranging from Sept. 22 to Oct. 21.

252. *Zonotrichia leucophrys leucophrys* (Forster). **White-crowned Sparrow.** This sparrow is a regular migrant, but is by no means common. It is found in the same situations as the White-throated Sparrows with which it is sometimes associated. Flocks of eight to ten birds are occasionally met with, but more often there are only singles or pairs. It is decidedly less social than the other sparrows, the order seemingly being every White-crown for himself. The Pharmaceutical Gardens is a favored locality. Here Mr. John Gundlach banded eight birds in the spring of 1927, and Mr. Harry Anderson, several in the spring of 1928. It arrives the second week in May, the

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[109] Cahn, *l. c.*
[110] Auk 34 (1917) 219.
[111] Auk 39 (1922) 273.
[112] Auk 43 (1926) 557.
[113] Auk 43 (1926) 381.

average date being May 10; the earliest, May 4, 1919.[114] It has not been noted after May 21 (1929). The fall records are less numerous than the spring. Inclusive dates are Sept. 29 (1929) and Oct. 16 (1927).

Kumlien and Hollister[115] state that in 1873 it nested on the north shore of Lake Monona, and has been known to remain throughout the summer at Lake Koshkonong. Stoddard[116] took an adult female in the Baraboo Bluffs, Sauk County, on June 6, 1921.

253. *Zonotrichia leucophrys gambeli* (Nuttall). **Gambel's Sparrow.** This subspecies of the White-crowned Sparrow is a rare straggler from the west. One was taken near Madison on May 17, 1919, by Mr. Warner Taylor.[117] I took an immature male on Oct. 16, 1927.

254. *Zonotrichia albicollis* (Gmelin). **White-throated Sparrow.** An abundant migrant frequenting the edges of woodland, and brushy roadsides and fields. Its song is a plaintive whistle. It arrives from the south from April 10 to 22, the average date being April 16; the earliest, April 8 (Taylor). The main movement takes place the first half of May. The migration is completed on the average by May 22, though stragglers remain until June, the latest date being June 7, 1914. The fall migrants arrive the middle of September, the average date being Sept. 17; the earliest, Sept. 7, 1918. The period of abundance is the first half of October. The migration is virtually completed by Oct. 25, though stragglers may be found until the end of November. I have found individuals wintering on several occasions. Considering the number of White-throated Sparrows that have been banded it is remarkable how few have been the recaptures. Prof. George Wagner informs me that he has had only two returns from 1900 banded birds.

The White-throated Sparrow is a common summer resident in the northern half of the state and may be found nesting sparingly even in the extreme southern portion. The evidence for its breeding in Dane County is circumstantial. One remained in a small marsh on East Washington Avenue in the summer

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[114] Taylor, Auk 37 (1920) 299.
[115] "Birds of Wisconsin," (1903), p. 98.
[116] Wilson Bull. 34 (1922) 78.
[117] Auk 37 (1920) 299.

of 1918, and was heard singing on numerous occasions from May 29 to Aug. 5. On May 16, 1920, I saw a female carrying nesting material in the swamp at the head of Lake Waubesa; and on July 25, 1925, I found an adult bird in a willow thicket at the Pheasant Branch marsh.

255. *Melospiza melodia melodia* (Wilson). **Song Sparrow.** This familiar sparrow is an abundant summer resident. It has adapted itself to all types of terrain. It arrives from March 11 to 25, the average date being March 18; the earliest, March 7, 1915 (Betts). It departs the end of October or early in November. The departure of stragglers is frequently delayed until the end of November, if the weather does not become severe. A few always winter about springs and spring runs.

Full sets of eggs have been found from May 1 to June 19, the majority during the middle of May. Young able to fly have been seen by May 23 (1915).

256. *Melospiza lincolni lincolni* (Audubon). **Lincoln's Sparrow.** This sparrow while resembling the Song Sparrow in appearance is entirely unobtrusive. It is a regular migrant in small numbers, but it probably more common than the records indicate. During the migration it is found in brushy situations and along the edge of woodland, usually close to the ground. When alarmed it will occasionally fly into a tree to a height of twenty or thirty feet and remain motionless. Generally, only a single bird is encountered, but on May 17, 1923, I saw a flock of six; and on Sept. 23, 1927, a flock of eight. First arrivals in spring have been noted from May 1 (1927) to May 14, the average date being May 10; while the last have been seen from May 17 to 24. It arrives in fall the last week in September. Inclusive dates are Sept. 23 (1927) to Oct. 22 (1916). I have taken specimens on the following dates: May 10, 1914; May 1 and Sept. 23, 1927; and May 20, 1928.

257. *Melospiza georgiana* (Latham). **Swamp Sparrow.** The Swamp Sparrow is an abundant summer resident in marshes containing standing water, though it does not refuse to nest where the ground is merely moist. The song is a trill like that of the Chipping Sparrow, but richer and more musical. To be fully appreciated it should be heard on a dark, quiet June night. It arrives April 3 to 18, the average date being April 12; the earliest, March 25, 1928. Departure takes place the end of

October, occasionally in November, the average date being Oct. 23; the latest, Nov. 24, 1923. There is one winter record. Mr. John Main saw one Dec. 30, 1929.

Nests with eggs have been found from May 30 to June 12.

258. *Calcarius lapponicus lapponicus* (Linnaeus). **Lapland Longspur.** If, at the end of March or the beginning of April, a blizzard comes out of the northwest, the chances are excellent that the Longspurs will be stopped in their migration. On certain hills swept bare by the wind they may be found feeding by hundreds. As if infected by the spirit of the storm, the birds, chattering ceaselessly, circle about in large groups from place to place. The Lapland Longspur is irregular both as to movements and numbers. It arrives from March 12 to April 5. The latest date on which it has been seen is April 25, 1928. Stoddard[118] found several large flocks in Dodge County as late as May 18 (1921). In autumn it arrives rarely by the end of October, the main movement taking place in November. The earliest date is Sept. 23, 1928, when a lone bird in breeding plumage was seen; in the case of November birds, the winter plumage is almost complete. Small groups winter commonly, occasionally large flocks. One numbering 500 was seen Dec. 28, 1913.

259. *Calcarius pictus* (Swainson). **Smith's Longspur.** Smith's Longspur is a rare migrant in Wisconsin. There are no records for Dane County but Stoddard[119] found them intermingled with Lapland Longspurs on the Sauk prairie on April 27 and 28, 1921. On the latter date between twenty and thirty were seen. Two females and one male in almost complete summer dress were collected. Taylor[120] mentions seeing one in the same locality on April 17, 1922. This species is confined in winter and during the migrations to a narrow belt of the great plains extending from Texas to Saskatchewan. Occasionally, by a fan-wise movement the migration extends across southwestern Wisconsin. On several occasions it has been abundant in the Chicago area,[121] from March 30 to May 5, and Oct. 3 to

[118] Wilson Bull. 34 (1922) 77.
[119] Wilson Bull. 34 (1922) 77.
[120] Auk 40 (1923) 339.
[121] Woodruff, "Birds of the Chicago Area," (1907) p. 134.

11. A more recent record is one taken by Eifrig[122] on May 1, 1912.

260. *Plectrophenax nivalis nivalis* (Linnaeus). **Snow Bunting.** The Snow Bunting is an irregular winter visitor and is much less numerous than the Lapland Songspur with which it frequently associates. On Dec. 19, 1926, I saw a flock of 100 feeding on ragweed in a stubble field. In February, 1930, it was again common.[123] Usually only single birds or flocks of twenty-five to thirty are met with. In the winter of 1913-14, it was present from Nov. 16 to April 5. On the latter date one of the birds was in song. It usually arrives in November or December and departs in March. The earliest date of arrival from the north is Oct. 21, 1928, when a single bird was found on the north beach of Lake Kegonsa.

ADDENDUM.

261. *Oiedema americana* Swainson. **Scoter.** This species appears to be of rare occurrence on the inland lakes. On Nov. 2, 1930, Mr. L. D. Atkinson, an experienced wild fowl hunter, informed me that he had shot that day a pair of ducks new to him. The bird in his possession, a young male Scoter, he kindly gave to me, and it is now in my collection. The other duck stated to have been identical with the above, had been given away. Before it could be rescued, it had been dressed for the table.

ACCIDENTAL AND EXTINCT SPECIES.

262. *Grus canadensis canadensis* (Linnaeus). **Little Brown Crane.** This species no longer occurs east of the Mississippi. Though there is always the possibility of an accidental visitor, it should be borne in mind that Kumlien and Hollister[124] give but two authentic records for Wisconsin, one being for Dane County: "At least one other, that we are positive of, was shot in Dane County late in the fall of 1879, and came into the possession of Thure Kumlien frozen stiff. This specimen was formerly in the Museum of Albion Academy."

263. *Pedioecetes phasianellus campestris* Ridgway. **Prairie Sharp-tailed Grouse.** This species was formerly abundant in

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[122] Auk 30 (1913) 239.
[123] Auk 47 (1930) 424 and 579.
[124] "Birds of Wisconsin," (1903) p. 37.

southern Wisconsin[125] but is now confined to suitable localities in the northern half of the state. A specimen taken at Janesville in October, 1869, is the last record for southern Wisconsin.[126] The only specific reference to its former occurrence in Dane County that I have found is the statement of T. M. Brewer under *P. p. columbianus:* "I — — — have from time to time had their eggs from Dane County, Wisconsin".[127]

264. *Ectopistes migratorius* (Linnaeus) **Passenger Pigeon.** The Passenger Pigeon was formerly very abundant in Dane County. Mrs. Roseline Peck, of the first resident family of Madison, stated: "——I stood (May 31, 1837) in the doorway watching flights of pigeons until late in the evening——."[128]

Mrs. S. M. Sutherland of Madison has informed me that Mr. Nicholas Haight of the town of Fitchburg killed one dozen pigeons on Sept. 17, 1872, the date being fixed by the fact that these pigeons were served at her first wedding anniversary. Mr. A. B. Morris has written that to the best of his recollection, the last time he killed pigeons was in 1876 or 1877. Favorite shooting grounds were the Turville farm on Lake Monona, the O'Malley farm three miles north of Mendota Station, the woods west of the Dudgeon School on Monroe Street, and a pond about two miles west of West Middleton.

The latest date of their occurrence, 1886, is furnished by Dr. S. H. Chase: "In the year 1886 my brother brought home several bags of wild pigeons. During the spring of 1885 while the wet snow was deep on the ground, one of my brothers and I hunted every day during our spring vacation; each day we saw, presumably, the same flock of eleven pigeons. However, at no time did we get any of them. Later, my older brother succeeded in bringing some of them to bag." He adds that about the year 1880 pigeons were still numerous and not hard to approach.

The last authentic records for the state are: one shot at Delavan Lake, Walworth County, Sept. 8, 1896;[129] and a pair seen in Dunn County on May 5, 1898 by J. N. Clark.[130]

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[125] Ridgway, "Birds of Illinois" 2 (1895) 14.
[126] Kumlien and Hollister, *l. c.* p. 58.
[127] Baird, Brewer, and Ridgway, "North American Birds", 3 (1874) 437.
[128] Wis. Hist. Coll. 6 (1872) 354.
[129] N. Hollister, Auk 13 (1896) 341.
[130] Kumlien and Hollister, "Birds of Wisconsin," (1903) p. 59.

265. *Meleagris gallopavo silvestris* Vieillot. **Wild Turkey.** I have been unable to obtain an entirely satisfactory record of the occurrence of the Wild Turkey in Dane County. The sole reason for including it in this list is the statement: "Thure Kumlien had no records for Lake Koshkonong later than 1842."[128] Under date of Jan. 29, 1929, Mr. H. L. Skavlem of Janesville wrote that he had no positive record for Dane County and adds: "I believe I am about the last living person that has the recollection of seeing a really wild turkey in this part of the country. I have the very distinct memory of seeing "Pip" (Philip) Goss with a large turkey hung on his shoulder with his gun, and showing father the big bird."[131]

The Wild Turkey apparently was not common in Wisconsin except in the southeastern and southwestern sections. Dr. Hoy[133] stated that the last were killed at Racine in the fall of 1846. Turkeys were abundant until the hard winter of 1842-3, when the snow was two feet deep with a firm crust in March. Inability to get to the ground to obtain food nearly exterminated the species. According to James Lockwood,[134] about the year 1820, it was not an uncommon thing to see a Fox Indian arrive at Prairie du Chien with a hand sled on which were twenty or thirty Wild Turkeys that he had for sale "as they were very plenty about Cassville." In Walworth County, fourteen Wild Turkeys were seen in the town of Spring Prairie, in October,1836; and a year or two later a flock of nearly thirty wintered, some of them being killed.[135]

HYPOTHETICAL

Gavia stellata (Pontoppidan). **Red-throated Loon.** The record of a bird still in winter plumage seen by me[136] on Lake Mendota, June 6, 1916, is not acceptable in the absence of a specimen. L. Kumlien[137] stated that he saw a dozen or more in Door County in June, 1881. This species occurs on Lake Michigan in winter, but is rare inland.

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[128] Kumlien and Hollister, *l. c.* p. 58.

[131] This without doubt is the 1854 record of Mr. Skavlem for the town of Newark, Rock County, cited by Kumlien and Hollister.

[133] Wis. Acad. 5 (1877-81) 255.

[134] Wis. Hist. Coll. 2 (1903) 132.

[135] C. M. Baker, Wis. Hist. Coll. 6 (1908) 465.

[136] Auk 34 (1917) 219.

[137] "Birds of Wisconsin", (1903) p. 7.

Sterna paradisaea Brünnich. **Arctic Tern.** A sight record for the Arctic Tern has been reported.[138] It is seldom found far from the sea, and Bent[139] considers that interior records are "none too well established".

Dendroica kirtlandi (Baird). **Kirtland's Warbler.** This rare warbler was seen near Madison on May 19, 1917 by Mr. Warner Taylor.[140] Kumlien and Hollister[141] state that a wounded bird of this species actually escaped from their hands near Lake Koshkonong on May 24, 1893. Obviously, until a specimen is taken it cannot be admitted to the state list.

SUPPLEMENTARY NOTES.

20. *Mareca penelope* (Linnaeus). **European Widgeon.** One was seen by Mr. John Main[142] and Mr. Warner Taylor on April 27, 1930.

34. *Clangula hyemalis* (Linnaeus). **Old-squaw.** Mr. Clarence S. Jung told me that he saw an Old-squaw at the outlet of Lake Monona on Dec. 6, 1920. Prof. George Wagner has informed me that he identified a female Old-squaw shot on Lake Monona by Mr. George Soehnlein, Dec. 1, 1930.

53. *Falco columbarius columbarius* Linnaeus. **Pigeon Hawk.** Mention of the collection of a specimen near Mazomanie on May 2, 1921 by Mr. H. L. Stoddard,[143] was inadvertently omitted from Part I.

58. *Perdix perdix perdix* (Linnaeus). **Hungarian Partridge.** Mr. Wallace Grange informs me that during the first two weeks of June, 1929, Mr. Knute Lee of Deerfield showed him a nest of this species containing 21 eggs. Both of the old birds were seen. According to Mr. Lee the Hungarian Partridge is becoming fairly common in certain sections near Deerfield. Twelve birds shipped from the state game farm at Fish Creek were liberated in the vicinity of Lake Wingra by Mr. Frank Schultz on April 23, 1929.

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[138] Taylor, Auk 40 (1923) 339.
[139] "North American Gulls and Terns", Bull. U. S. Nat. Museum No. 113 (1921) 255.
[140] Auk 34 (1917) 343.
[141] "Birds of Wisconsin", (1903) p. 133.
[142] Auk 47 (1930) 578.
[143] Wilson Bull, 34 (1922) 74.

76. *Catoptrophorus semipalmatus inornatus* (Brewster). **Western Willet.** Three birds of this species were found in a marsh near Madison by Mr. Main[144] on May 2, 1930. He courteously informed me of their occurrence, so that I saw them the evening of the same day.

90. *Lobipes lobatus* (Linnaeus). **Northern Phalarope.** Mr. John Main[145] observed this species on several occasions from May 17 to 24, 1930, on one day as many as seven being seen. I took a female in full breeding plumage from a flock of four birds on May 24, 1930.

102. *Tyto alba pratincola* (Bonaparte). **Barn Owl.** I took a female Nov. 24, 1929.[146] Mr. Paul Errington found a dead bird of this species on Feb. 10 and another on Feb. 14, 1930, in a quarry near Madison. Examination indicated that these birds had died of starvation and cold.

109. *Cryptoglaux acadica acadica* (Gmelin). **Saw-whet Owl** Apparently this species is not as rare as I had supposed. Mr. Herbert Stoddard, who has a flair for raptors, found a Saw-whet Owl near Pine Bluff on March 15, 1930. The following day while I was with him on a field trip, he had the temerity to point out another sitting in a small cedar. The locality was in the southwestern corner of Columbia County, near the Dane County line.

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[144] Auk 47 (1930) 578.
[145] Auk 47 (1930) 578.
[146] Auk 47 (1930) 424.

EXTREMES OF TEMPERATURE IN WISCONSIN.

ERIC R. MILLER

The highest and lowest temperatures ever recorded in Wisconsin form the subject of this paper. It seems desirable to say something about how, when, where and by whom the temperatures were observed and recorded.

The earliest observations were made as a routine duty by the hospital surgeons of the army posts of Fort Crawford (Prairie du Chien), Fort Winnebago (Portage), and Fort Howard (Green Bay). The first of these were made in 1820. In the 40's the services of civilians were enlisted by James Pollard Espy for the scientific investigation of storms. Espy was connected with the Surgeon-General's Office in the War Department, and subsequently with the Navy Department. Among those who coöperated with Espy and his successors a group of Milwaukeeans consisting of Increase A. Lapham, E. S. Marsh, and Carl Winkler deserve special mention because they maintained a continuous series of observations from 1843 to 1871. After the organization of the Smithsonian Institution, its head, the distinguished pioneer physicist Joseph Henry organized a country-wide corps of weather observers, equipped with standardized instruments, that was represented in Wisconsin by 35 all told. Of these only a few worked for more than a year or so, and rarely more than 4 or 5 simultaneously. From 1860 to 1871 the Lake Survey made very exact observations at Superior and Milwaukee. In 1870 our present national weather service was organized by the Chief Signal Officer of the Army, with its network of stations reporting by telegraph, and manned by professional observers. The coöperative observers were merged in this organization in 1874, but their number did not increase appreciably until the period between 1889 and 1891 when the organization now known as the Climatological Service of the Weather Bureau came into being. Since then from 60 to 90 coöperative observers, equipped with standardized instruments, and well distributed over the state, have gradually accumulated a vast store of statistical data.

The earlier observers were not supplied with registering thermometers, but made readings at stated times during the day on a schedule designed to catch the highest and lowest at their usual times of occurrence, viz., sunrise, or 7 a. m. and 2

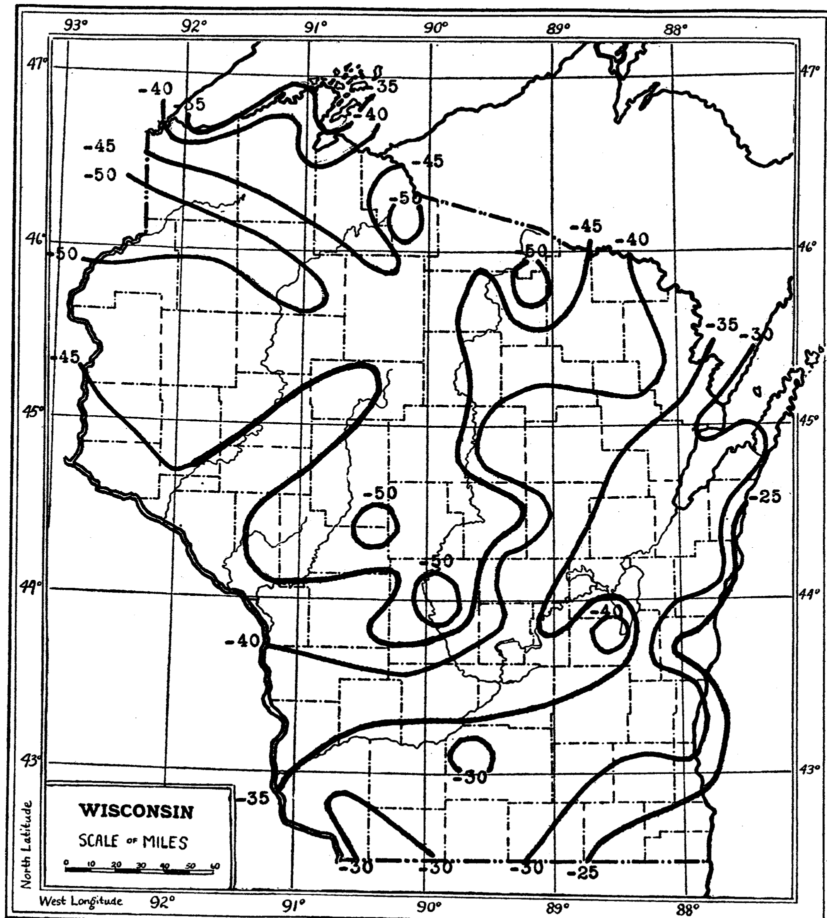

Fig. 1. Map of the state of Wisconsin, showing the distribution of the lowest recorded temperatures.

p. m. Maxima and minima at other hours were not recorded. Lapham who made the observations for the Lake Survey operated both methods, so that we are able to compare them. On January 1, 1864, his registering thermometer indicated —30, but the lowest at any of the fixed hours was —22. This difference may explain why so few of the extremes recorded in early years surpass those of later years.

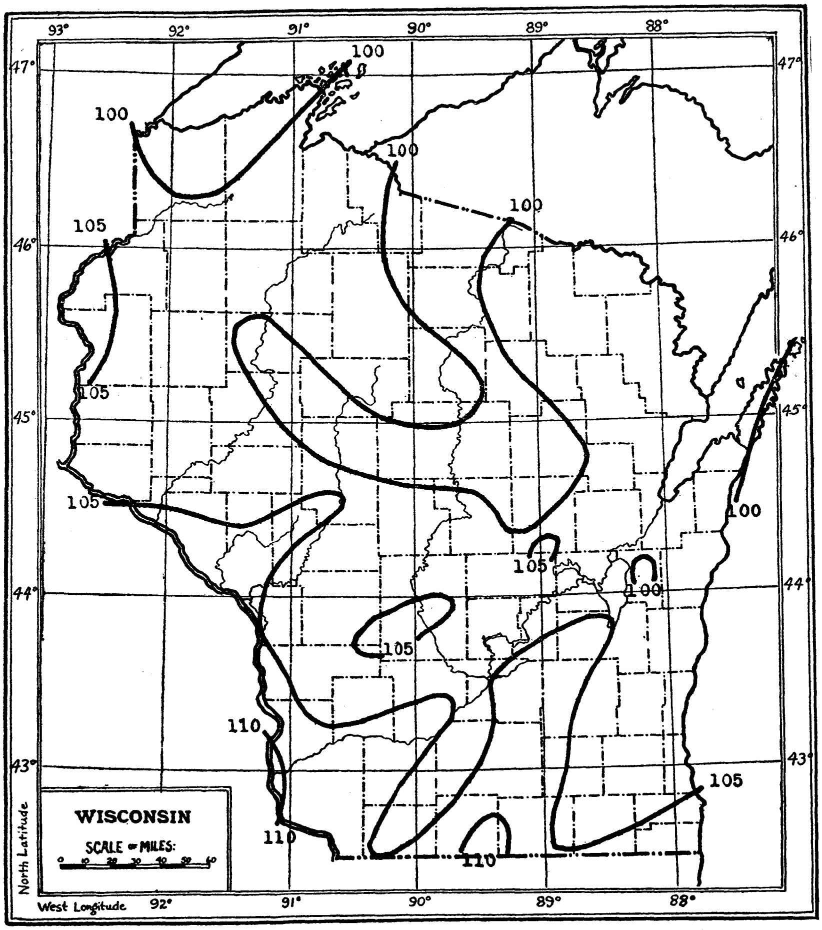

Fig. 2. Map of the state of Wisconsin, showing the distribution of the highest recorded temperatures.

The early observers exposed their thermometers in the open, while nowadays, thermometers are mounted in louvred shelters. Comparison of the average temperature at 2 p. m. in early series of observations, with the average for the same hour under modern conditions, indicate that the thermometers must then have been exposed to the direct rays of the sun. It is remarkable that in spite of this, the record high temperatures were mostly reached under modern conditions.

All of the earlier observers, and most of the present-day coöperative observers differ from the regular Weather Bureau stations in that their thermometers are exposed only a few feet above the ground, while the Weather Bureau Offices, necessarily located in the business section of cities have their thermometers exposed on buildings, which are steam-heated. The effect of this difference is easily seen in the records of extreme temperatures, especially of the minima. For example, on February 19 and 20, 1929, the following minima were reported by coöperative observers: —33 at Watertown, —35 at Brodhead, —36 at Darlington, and —40 at Richland Center. At the Weather Bureau office at Madison, a thermometer, 70 feet above the ground, read —21. At Milwaukee, —9 was the lowest reached at the Weather Bureau Office at the Federal Building, but the branch office at the airport at Cudahy reported —29.

Radiation is a very important factor in producing extremes of temperature; radiation from the sun warming the ground, to produce maxima; radiation from the ground to the sky to produce minima. Greater extremes are therefore likely to be reached at thermometers exposed near the ground. The air is stiller near the ground, and this also favors greater extremes.

Snow has a special relation to the occurrence of low temperatures, when it covers the ground to a sufficient thickness. Snow is a good reflector of sunlight and daylight, and therefore a poor absorber of radiation from these sources. Its character changes entirely with reference to the long-wave radiation in which heat flows away from the earth to the sky. A snow surface radiates much heat away to the sky at night, and the air in contact with it cools rapidly, and as the density of the air becomes greater as it cools, the cold air remains in contact with the refrigerating surface, and also tends to discourage air circulation through increasing stability. The cold spell of January, 1922, when the record low temperature for the state, —54 at Danbury, Burnett County, was registered, occurred when the northern part of the state was buried under a heavy snow

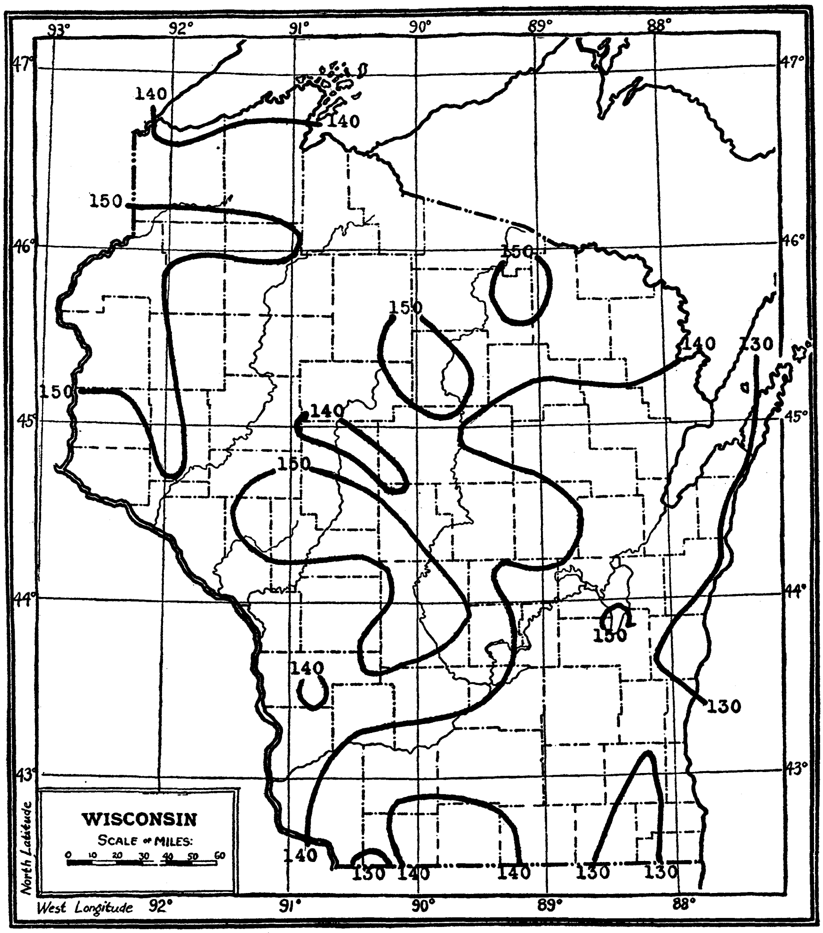

Fig. 3. Map of the state of Wisconsin, showing the absolute range of temperature in the various parts of the state.

cover. At Madison, where the snow cover averaged only .6 inch, the lowest temperature was —12.

The occurrence of the lowest temperature at Danbury has already been noted. The highest was 111° on July 4, 1901 at Brodhead. It is interesting to note that 28 of the 104 records of highest temperature date from July, 1901, while 23 of the minima were registered in February, 1899.

On the maps it is easy to note the moderating influence of the Great Lakes on both maxima and minima. Latitude also appears important in the distribution of minima. The irregularities on the maps may be ascribed to varying length of record, and differences in exposure, as well as to natural differences.

The table and maps accompanying this article are based mainly on data derived from the three publications listed in the bibliography.

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TABLE I

Extremes of Temperature in Wisconsin

Place	County	Highest	Date	Lowest	Date	Range
Amherst	Portage	99	July 24, 1901	—48	Feb. 11, 1899	147
Antigo	Langlade	100	July 2, 1911	—40	Feb. 10, 1899	140
Appleton	Outagamie	102	July 30, 1916	—32	Feb. 20, 1929	134
Ashland	Ashland	104	July 20, 1901	—38	Jan. 28, 1915	142
Barron	Barron	102	July 24, 1901	—48	Feb. 10, 1899	150
Bayfield	Bayfield	104	July 20, 1901	—33	Feb. 10, 1899	137
Beloit	Rock	105	July 21, 1901	—29	Jan. 1, 1864	134
Beloit	Rock	105	July 29, 1916			
Big St. Germain Dam	Vilas	100	July 2, 1911	—45	Jan. 28, 1915	145
Brodhead	Green	111	July 4, 1901	—35	Feb. 20, 1929	146
Burnett	Dodge	102	July 29, 1916	—34	Feb. 1, 1918	136
Butternut	Ashland	100	July 19, 1897	—43	Feb. 10, 1899	143
Cecil	Shawano	103	July 2, 1911	—33	Jan. 11, 1912	136
Chilton	Calumet	100	July 16, 1901	—34	Feb. 10, 1899	134
Coddington	Portage	100	Sept. 6, 1922	—43	Feb. 25, 1928	143
Cornucopia	Bayfield	99	July 28, 1917	—38	Jan. 26, 1927	137
Crandon	Forest	104	June 25, 1891	—37	Jan. 28, 1915	141
Danbury	Burnett	102	June 30, 1921	—54	Jan. 24, 1922	156
Darlington	Lafayette	105	July 5, 1911	—36	Feb. 20, 1929	141
Deerskin Dam	Forest	101	July 2, 1911	—46	Mar. 5, 1917	147
Delavan	Walworth	103	July 28, 1916	—29	Feb. 1, 1918	132
Deuster	Juneau			—47	Jan. 1888	
Dodgeville	Iowa	107	July 21, 1901	—31	Feb. 8, 1899	138
Downing	Dunn	103	July 26, 1894	—48	Feb. 10, 1899	151
Dubuque, Ia.		106	July 21, 1901	—32	Jan. 7, 1887	138
Duluth, Minn.		99	July 1, 1883	—41	Jan. 2, 1885	140
Easton	Adams	106	July 21, 1901	—50	Feb. 10, 1899	156
Eau Claire	Eau Claire	103	July 19, 1901	—40	Feb. 10, 1899	143
Florence	Florence	104	July 29, 1917	—39	Feb. 11, 1899	143
Fond du Lac	Fond du Lac	106	July 29, 1916	—44	Jan. 21, 1888	150
Grand River Locks	Marquette	103	July 29, 1916	—40	Feb. 20, 1929	143
Grantsburg	Burnett	105	July 16, 1894	—48	Jan. 12, 1912	153
Green Bay	Brown	101	July 28, 1916	—38	Feb. 1823	139
Green Bay				—36	Jan. 21, 1888	
Hancock	Waushara	103	July 28, 1916	—40	Feb. 25, 1928	143
Hatfield	Jackson	101	July 20, 1930	—51	Feb. 1, 1918	152
Hayward	Sawyer	102	July 20, 1901	—50	Feb. 4, 1907	152
High Falls	Marinette	103	July 29, 1917	—40	Feb. 25, 1928	143
Hillsboro	Vernon	106	July 21, 1901	—45	Jan. 12, 1912	151
Iron River	Bayfield	99	July 29, 1916	—42	Jan. 26, 1927	141
Kewaunee	Kewaunee	104	July 30, 1916	—25	Jan. 7, 1912	129
Kilbourn	Columbia	104	July 20, 1906	—38	Feb. 20, 1930	142
Knapp	Dunn	103	July 26, 1894	—48	Feb. 10, 1899	151
Koepenick	Langlade	100	July 29, 1916	—42	Jan. 7, 1912	142
La Crosse	La Crosse	104	July 21, 1901	—43	Jan. 18, 1873	147
Lake Mills	Jefferson	107	July 21, 1901	—32	Feb. 20, 1929	139
Lancaster	Grant	107	July 21, 1901	—30	Feb. 13, 1905	137
Long Lake	Oneida	103	July 2, 1911	—50	Jan. 28, 1915	153
Madison	Dane	104	July 21, 1901	—29	Jan. 1, 1864	133
Manitowoc	Manitowoc	100	July 30, 1916	—32	Jan. 9, 1875	132
Marshfield	Wood	98	July 11, 1921	—35	Jan. 28, 1915	133
Mather	Juneau	101	June 29, 1910	—44	Feb. 20, 1929	145
Mather	Juneau	101	Sept. 6, 1922			
Meadow Valley	Juneau	104	July 28, 1916	—48	Feb. 19, 1929	152
Medford	Taylor	103	June 19, 1900	—45	Feb. 10, 1899	148
Menasha	Winnebago	100	July 11, 1921	—27	Feb. 20, 1929	127
Merrill	Lincoln	103	July 30, 1917	—48	Jan. 12, 1909	151
Milwaukee	Milwaukee	102	July 30, 1916	—30	Jan. 1, 1864	132
Milwaukee County Airport	Milwaukee	103	July 20, 1930	—29	Feb. 20, 1929	132
Minocqua	Oneida	99	June 29, 1910	—48	Jan. 28, 1915	147
Mondovi	Buffalo	100	July 27, 1916	—42	Jan. 1, 1918	142
Mount Horeb	Dane	103	July 5, 1911	—30	Jan. 7, 1912	133
Muscoda	Grant	105	July 29, 1916	—35	Jan. 12, 1912	140
Neillsville	Clark	106	July 24, 1901	—48	Jan. 1886	154
New London	Waupaca	104	June 30, 1910	—37	Feb. 10, 1899	141
New Richmond	St. Croix	100	June 29, 1910	—42	Jan. 28, 1915	142
Oconto	Oconto	102	July 30, 1916	—30	Feb. 10, 1899	132
Osceola	Polk	105	July 20, 1901	—47	Feb. 10, 1899	152
Oshkosh	Winnebago	104	July 28, 1916	—34	Feb. 20, 1929	138
Park Falls	Price	100	July 29, 1917	—45	Jan. 24, 1922	145
Pine River	Waushara	103	July 29, 1916	—36	Feb. 10, 1899	139
Plum Island	Door	100	July 30, 1916	—26	Jan. 13, 1929	126
Plymouth	Sheboygan	103	July 29, 1916	—25	Feb. 1, 1918	128

TABLE I

Extremes of Temperature in Wisconsin

Place	County	High-est	Date	Low-est	Date	Range
Portage	Columbia	106	July 21, 1901	—37	Feb. 1, 1918	143
Port Edwards	Wood	103	July 27, 1916	—44	Feb. 1, 1918	147
Port Washington	Ozaukee	103	July 2, 1911	—31	Jan. 24, 1904	134
Prairie du Chien	Crawford	110	July 22, 1901	—36	1821	146
Prairie du Chien	Crawford			—34	Jan. 12, 1912	
Prairie du Sac	Sauk	106	July 5, 1911	—36	Feb. 20, 1929	142
Prentice	Price	102	June 24, 1900	—48	Jan. 28, 1915	150
Racine	Racine	107	July 10, 1901	—24	Jan. 25, 1904	131
Red Wing, Minn.		106	July 1901	—41	Jan.,	147
Reedsburg	Sauk	103	July 29, 1916	—40	Feb. 1, 1918	143
Rest Lake	Iron	98	Aug. 18, 1925	—51	Feb. 25, 1928	149
Rhinelander	Oneida	98	June 29, 1910	—41	Jan. 28, 1915	139
Ripon	Fond du Lac	103	July 29, 1916	—28	Jan. 21, 1924	131
St. Paul, Minn.		104	July 24, 1901	—41	Jan. 21, 1888	145
Shawano	Shawano	98	July 20, 1901	—39	Feb. 11, 1899	137
Sheboygan	Sheboygan	104	July 20, 1930	—25	Jan. 25, 1904	129
Shullsburg	Lafayette	102	July 29, 1911	—28	Jan. 28, 1915	130
Solon Springs	Douglas	99	June 22, 1911	—50	Feb. 4, 1907	149
Spooner	Washburn	102	July 27, 1894	—46	Feb. 5, 1895	148
Stanley	Chippewa	98	July 1, 1910	—41	Jan. 6, 1912	139
Stevens Point	Portage	101	July 20, 1930	—48	Feb. 10, 1899	149
Sturgeon Bay	Door	100	June 30, 1910	—35	Feb. 10, 1899	135
Superior	Douglas	99	July 12, 1866	—35	Jan. 12, 1912	134
Tomahawk	Lincoln	98	July 27, 1916	—43	Jan. 28, 1915	141
Valley Junction	Monroe	101	June 30, 1910	—44	Feb. 10, 1899	145
Viroqua	Vernon	103	July 21, 1901	—33	Jan. 12, 1912	136
Vudesare	Vilas	100	July 2, 1911	—47	Jan. 28, 1915	147
Wabasha, Minn.		108	July, 1894	—36	Feb., 1899	144
Watertown	Jefferson	104	July 21, 1901	—33	Feb. 20, 1929	137
Waukesha	Waukesha	103	July 27, 1916	—27	Jan. 25, 1904	130
Waupaca	Waupaca	105	July 20, 1930	—41	Feb. 20, 1929	146
Wausau	Marathon	99	July 2, 1911	—40	Feb. 10, 1899	139
Weyerhaeuser–	Rusk	98	July 20, 1901	—48	Jan. 6, 1912	146
Whitehall	Trempealeau	105	July 27, 1916	—49	Jan. 7, 1912	154
Williams Bay	Walworth	100	July 20, 1930	—25	Jan. 18, 1930	125
Winter	Sawyer	95	July 11, 1921	—52	Jan. 28, 1915	147
Wisconsin Rapids	Wood	102	July 19, 1930	—43	Feb. 19, 1929	145

THE GEOGRAPHY OF THE NORTHWESTERN PINE BARRENS OF WISCONSIN

RAYMOND E. MURPHY

INTRODUCTION

The Barrens Landscape. The Northwestern Pine Barrens of Wisconsin is a long, narrow strip of sand (Figure 1) where coniferous forests and open expanses of sweet fern and grassy barrens[1] dwarf into insignificance the few evidences of man's present occupancy and use of the land. Although the area is dominantly a southwestward sloping plain, numerous pits interrupt the plain surface in some portions, their presence introducing sufficient unevenness locally to justify classification as hill country. The drainage pattern presented by the sand plain is poorly developed, and there are large areas unpenetrated by streams and many lakes without outlets. Despite some topographic variability, the Barrens has many elements of unity—a unity which is further emphasized by the way in which it contrasts with neighboring areas (Figure 2).[2]

Jack pine predominates in the forests, either in pure stands of thickly set trees, or mixed with the useless, ubiquitous scrub oak.[3] Great piles of jack pine bolts[4] in clearings along the

[1] The term "barrens" is used throughout this paper in two senses. The unused open tracts with only a grass or sweet fern cover are referred to as barrens in the sense of being bare and unproductive. The sand strip as a whole has long been referred to as "the Barrens" and this usage is followed here, capitalization serving to distinguish the region name from the purely descriptive term.

[2] The boundaries of the Barrens as used in this study were based primarily upon the map of the Wisconsin Soil Survey (Figure 3). The continuous area of Plainfield and Vilas soils in the St. Croix Valley and farther northeast, as shown on this map, was considered as being essentially coincident with the Barrens, other types of soil being included only where they existed as small islands or narrow strips in the continuous body of Plainfield and Vilas. In most cases the boundary thus set was found to be justified by its coincidence with a marked change in vegetation cover and use of the land. This gave a basis for arbitrary use of the soil boundary as a regional boundary in localities where the transition in use and vegetation is more gradual. In Burnett County one area of Plainfield Sand was considered as part of the region even though isolated from the main body of the Barrens.

[3] The term "scrub oak" is commonly applied to the small bush-like oaks observable throughout the Barrens. Several species of oak are included under this general name, but scarlet oak is said to be the most common.

[4] The eight-foot lengths of jack pine, ready for shipment to the pulp mills, are ordinarily referred to as "bolts" or "boltwood".

railroads or at railway stations await the call of the pulp mills of Central Wisconsin, and clumsy truck loads of similar logs are met jogging along the two-rut, sand roads which crisscross the Barrens. The grassy and sweet fern barrens bear no mark of present utilization, but are desolate open tracts where only an occasional charred stump, a cluster of jack pines, or a scrub oak bush, breaks the monotonous sweep of the rolling, thinly clad ground surface.

At rare intervals small cultivated areas with isolated tar paper shacks or log cabins interrupt the continuity of forest and barrens. The Scandinavian ancestry of the owners of many of these humble homes is indicated by the frequent recurrence of such names as Anderson, Johnson, and Christianson on the mail boxes. Typically, the farmstead scene does not include children playing around the house and barns. There are some large families, of course, but the region is characteristically one of people past middle age—weatherworn old Scandinavians who came here with their wives and children many years ago. The children have grown up and gone. The Barrens does not hold its younger generation. No new settlers are moving in, and one gets the impression that when the present hardy survivors pass on there will be none to take their places.

Cropped fields, dominantly hay, are unfenced, but adjacent wood or barrens lots, where a few cattle showing traces of Jersey blood find scanty grazing, are enclosed by fences. These poorly fed and poorly cared for herds are the basis of a dairy industry in which cream, shipped to creameries in St. Paul, Duluth, and neighboring small towns, is the end product. The industry is, however, small-scale in character, with poor barns and equipment and meager returns.

Almost as numerous as the occupied farms are the abandoned, tumbled-down farmhouses surrounded by fields going to waste. Sometimes only a few stones and a patch of quack grass remain to mark the site of a former home, and to give the impression of poor land and unsuccessful farming.

Although the Northwestern Pine Barrens has an area of approximately 1500 square miles, it has but six small villages,[5] three of which are near the edge of the sand strip and derive

[5] Villages and populations (estimated): Iron River, 810; Grantsburg, 781; Solon Springs, 778; Gordon, 600; Wascott, 369; Delta, 12.

their trade largely from farms located on neighboring areas of better soil, while the others are so situated with respect to lakes that they owe their prosperity, such as it is, to summer

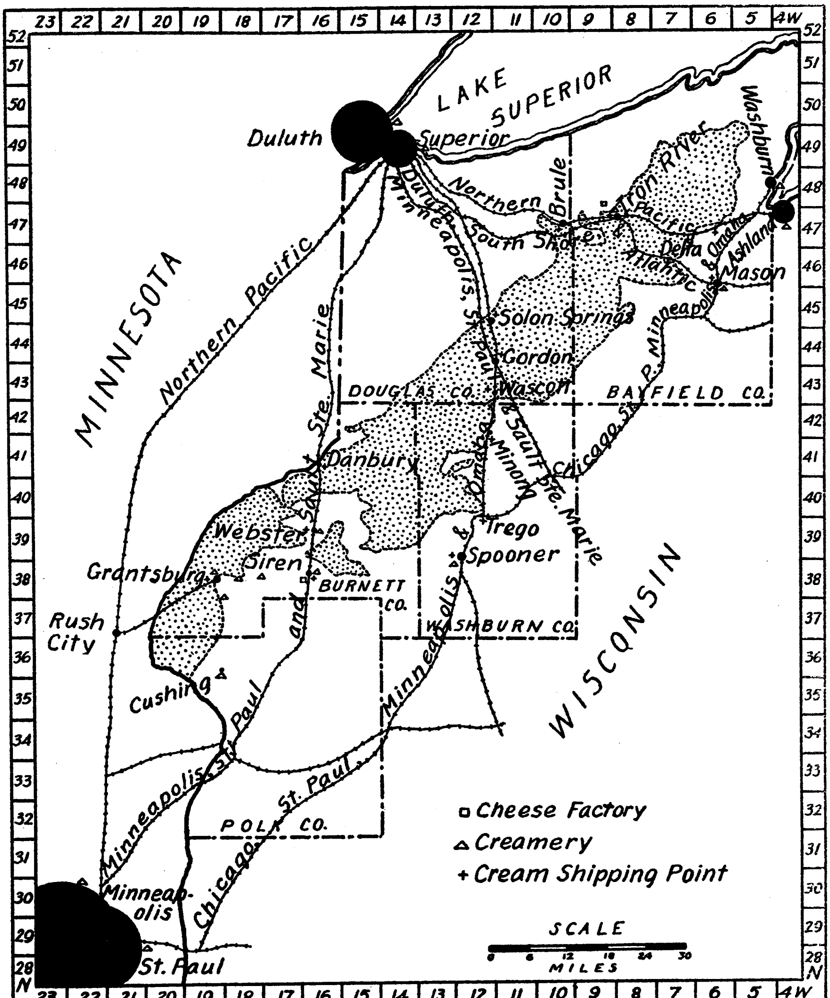

FIGURE 1. Map of a part of Wisconsin showing location and extent of Northwestern Pine Barrens. The principal villages of the Barrens and nearby villages, towns, and cities to which the area is related by trade are shown by dots, the areas of which are proportional to population. The creameries, cheese factories, and cream shipping points shown are those which receive all or any of their cream from the Barrens. The single

creamery symbol in the case of the larger cities represents not a single creamery but several which receive some cream from the Barrens. Practically all the cream shipping points on the railroads, and a number of spurs and sidings which are not cream shipping points, ship jack pine bolts.

resorts. Many of the pits which characterize portions of the Barrens hold lakes whose clear water and sandy bottoms attract summer visitors. Wooded shores of the larger lakes are the sites of expensive summer homes and resorts which seem strangely out of place in this unfruitful country.

Occasional swampy areas present still another type of landscape. Some are clothed with tamarack, spruce, and muskeg, but others, even more extensive tracts, are treeless swamp meadows.

From the top of the occasional fire lookout tower which projects above the general level, the country is a wide expanse of alternating forest and barrens, studded by many lakes with their summer homes and resorts, and broken by widely scattered farms and a rectangular network of roads.

Recent Stages in the Development of the Barrens Landscape. It is difficult to visualize the Northwestern Pine Barrens of Wisconsin as it must have appeared before marked by the hand of man. It had a forest cover, largely coniferous, but the forests of the sand strip as a whole averaged poorer and sparser than those on the heavier soils to north and south.[6] Such types as jack pine and scrub oak, which do well on poor soil, must have been fairly common even then, but many Norway pines and a limited number of white pines grew in parts of the Barrens.

Before the coming of logging concerns and settlers, the Barrens was part of the domain of the Ojibwa (Chippewa) Indians who, during the sixteenth and seventeenth centuries, had driven the Fox and Dakota tribes from the area.[7] The Ojibwa learned to use the wild rice that grows in the swamps of Northern Wisconsin and this grain became an important part of their food.[8] There is a legend that the Indians burned over sections

[6] Roth, Filibert, Forestry conditions of Northern Wisconsin, Wisconsin Geological and Natural History Survey, Bulletin 1, pp. 11-12, 1898.

[7] Jenks, Albert E., The wild rice gatherers of the upper lakes—a study in American primitive economics, 19th Annual Report of the Bureau of American Ethnology, pp. 1040-41, 1901.

[8] Jenks, Op. cit., p. 1042.

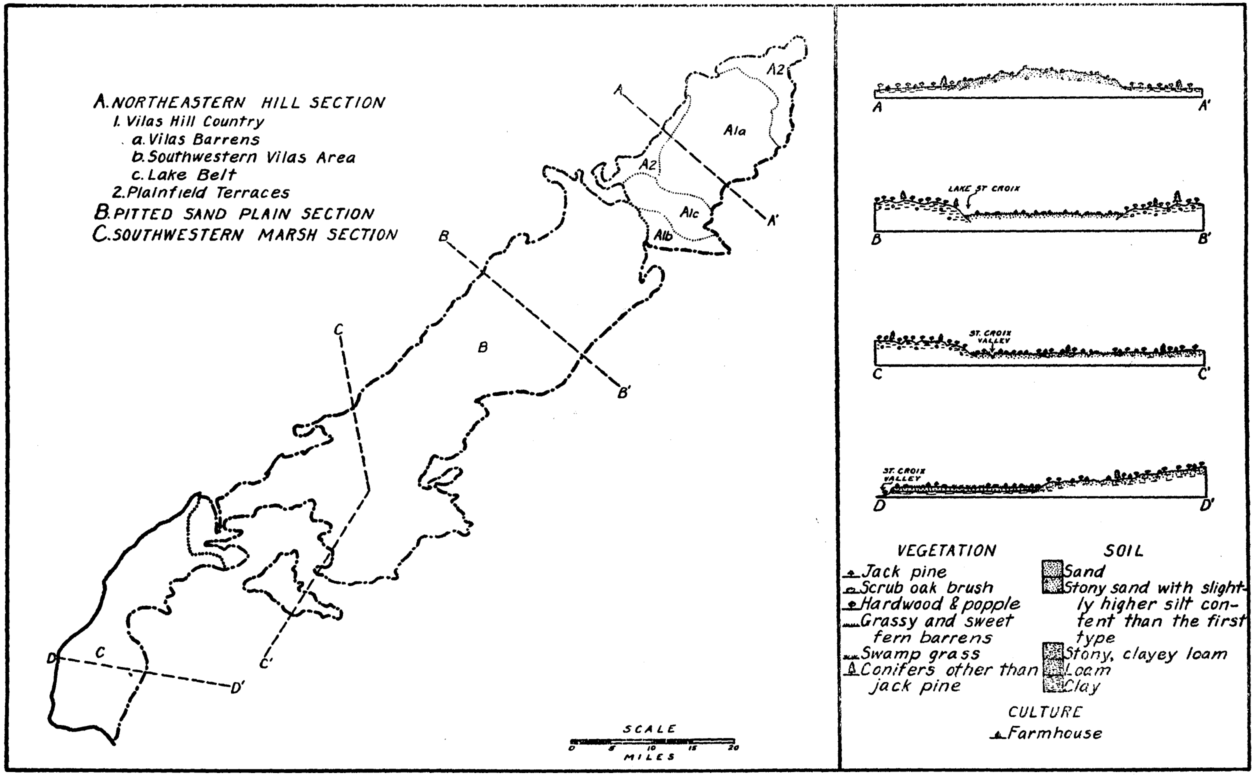

FIGURE 2. Geographic subdivisions of the Northwestern Pine Barrens with diagrammatic geographic cross sections at selected intervals. Note the changes in soil, cover, and utilization which mark the boundaries of the Barrens. Southwest of Grantsburg sand country continues beyond the St. Croix River into Minnesota, but the river and the state line which coincides with it divides the interests of the two states, and this fact, as well as convenience, dictated the setting of the boundary of the region covered by this study at the river. No attempt has been made to show bed rock conditions in the cross sections.

of the Barrens to improve the blueberry crop, and it is possible that they may thus have changed the landscape which they found.

The invasion of Northwestern Wisconsin by logging concerns about 1860 inaugurated an epoch of rapid changes in the appearance of the country. Most of the white pine was cut early in the logging period, and a considerable part of the Norway pine followed, leaving jack pine, scrub oak, and a few straggling Norway and white pines. The lumbering operations were followed by frequent fires. The loggers removed only the choicest pine, while on the forest floor they left great heaps of branches and tops known as "slashings". Such dead material

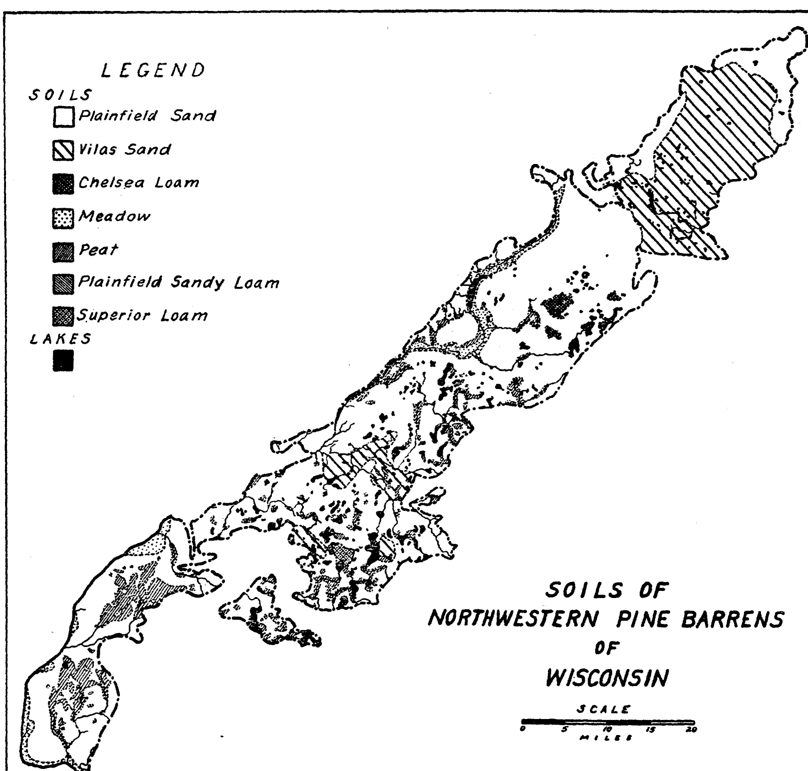

FIGURE 3. Soils of the Northwestern Pine Barrens of Wisconsin. (After Musbach, F. L., and others, Reconnaissance Soil Survey of North Part of North Western Wisconsin, Bulletin 32, Soil Series No. 6, Wisconsin Geological and Natural History Survey, 1914.)

dried out during periods of drought until only a spark from a hunter's camp fire, a passing locomotive, or a chance stroke of lightning was necessary to set it ablaze. Moreover, saw mills and saw mill towns were flimsily constructed of inflammable pine, and the fires which so commonly started in and wiped out these mills and towns swept over the surrounding country as well. Whatever the source, there was no attempt to check these early fires, and they were allowed to burn until they died out or were extinguished by rains.

Through the killing out of less hardy types such as white and Norway pines, fire furthered the spread of both jack pine and scrub oak.[9] In fact, jack pine is known as "fire" pine since fire opens the cones and prepares an ideal seed bed for the young trees, which spring up everywhere shortly after a fire has destroyed the better timber. If fire again sweeps the area before the young jack pines have produced cones, the region is then destined to be open land with a vegetation of thin grass, sweet fern, and scrub oak. Gradually then, during and following the period of lumbering, the axe of man, and, even more, the fires which he set, changed the aspect of the Barrens. Jack pine and scrub oak spread and thrived, becoming the dominant vegetation types.

At about the time of maximum lumbering operations settlers began to come into the Barrens, and the influx continued after lumbering had ceased. Some homesteaded for the timber on the land, and sold or abandoned their holdings after the timber was logged off. Others came as permanent settlers attracted in part by the ease of clearing and working the sandy soils. During this period of active settlement many roads were opened, particularly in the flatter areas where in some instances they marked every section line.

During the present century the farmers of the Barrens have encountered increasing difficulty in making a living in competition with those who settled on areas of better soils. The limited fertility of the sandy soil has been exhausted by continuous cropping with little rotation or fertilization, and many

[9] Bordner, J. S., and Morris, Wm. W., in Land Economic Inventory of Northern Wisconsin, by Whitson, A. R., et. al., Wisconsin Department of Agriculture and Markets in co-operation with the Geological and Natural History Survey and the Conservation Commission, Bulletin 100, pp. 58-59, 1929.

farms have been abandoned and allowed to revert to barrens or forest.

Cessation of lumbering operations was followed about 1910 by the development of a new timber industry, the cutting of jack pine for pulpwood. Selective cutting of trees of pulpwood size has materially thinned the stand of jack pine, although it has not destroyed whole stands except where fires have caught in the slashings. At the present time a forest protection service combats the fire hazard. A small force of men is regularly employed to man the several lookout towers and to be ready in case of emergency to organize and lead fire-fighting forces.

Coincident with the early development of the boltwood industry, summer resorts began to assume importance, although there was some resort activity even prior to the pulpwood industry in a few localities. So rapidly have summer homes and hotels sprung up along the shores of better lakes, that today the number of commercial resorts is too great in proportion to the number of visitors for the business to be very profitable.

GEOGRAPHIC SUBDIVISIONS OF THE BARRENS

Though the Northwestern Pine Barrens is uniform throughout in its general aspects, a more detailed consideration brings out certain contrasts. On the basis of these contrasts the area may be divided into three subregions (Figure 2):

(1) The Northeastern Hill Section (310 square miles)
(2) The Pitted Sand Plain Section (960 square miles)
(3) The Southwestern Marsh Section (220 square miles)

THE NORTHEASTERN HILL SECTION

The Northeastern Hill Section of the Northwestern Pine Barrens region of Wisconsin is a hilly interlobate moraine, fronted on the northeast and northwest by narrow, level terrace aprons (Figures 2 and 3). During the glaciation of Northern Wisconsin, one lobe of the ice sheet passed southwestward through the Lake Superior Basin to its head, spreading out fanwise to the south; while a second lobe traveled on a more southerly course by way of Chequamegon Bay.[10] The fanwise spread of the second, the Chippewa Lobe, brought it

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[10] Martin, Lawrence, The Physical Geography of Wisconsin, Wisconsin Geological and Natural History Survey, Bulletin 36, p. 374, 1916.

into conflict with the spreading Superior Lobe, and along this zone of contact a pile of debris was heaped up, the Bayfield Ridge of today. The material of this high, hummocky belt is largely sand, a reflection of the sandstone bed rock. While the ice front was retreating, a marginal lake existed in the Lake Superior Basin, and it is supposed that the work of the waves at a high stage of the lake developed the terraces which fringe the Ridge. During this and later stages of the marginal lake the clays of the Lake Superior Lowland were laid down.

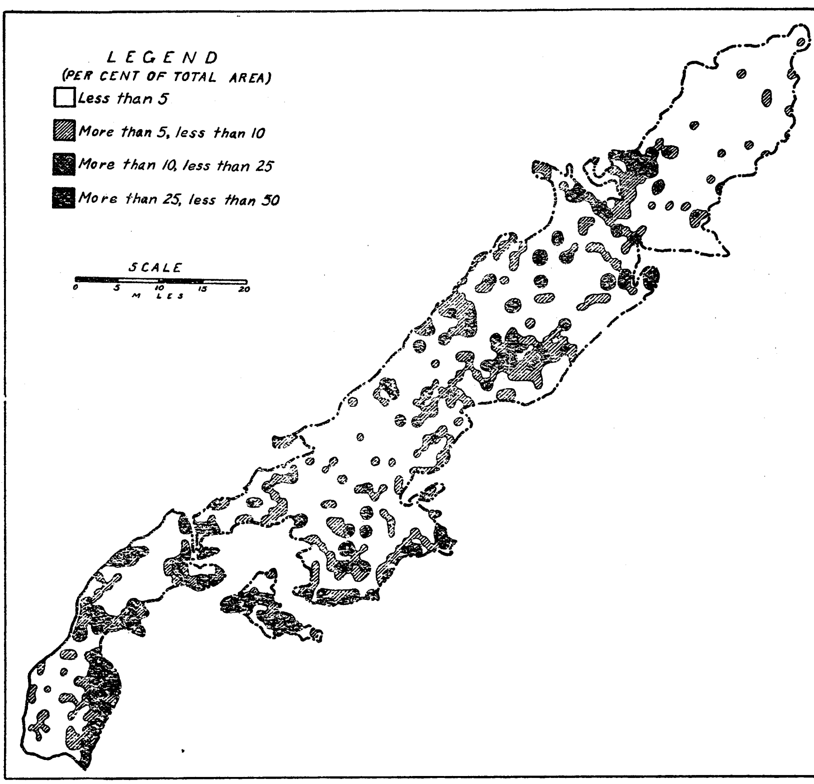

FIGURE 4. Cultivated Land in the Northwestern Pine Barrens of Wisconsin, 1929. (Based on field mapping by the author.)

Typical Barrens vegetation characterizes the Northeastern Hill Section, but the degree of utilization is low even when judged by standards based on the sand strip as a whole. Although it consists of both hill country and flat terrace land, the section does not present as many contrasts in natural and cultural forms as this variability would seem to suggest. Alternate patches of forest and sweet fern barrens cover hills and flats alike, while meagerness of utilization is typical of both bench and hill land. Thus topographic differences seem to have been less significant than soil similarity in the development of the present cover features. This fact is well illustrated by the marked vegetation and utilization change that may be observed in passing either from the flats or the hill country to neighboring areas of heavier soil (Figure 2).

Small, isolated farms are widely scattered over the Northeastern Hill Section, frequently miles apart, but dotting hills and terraces alike (Figure 4).[11] Scattered though they are,

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[11] The quantitative data used in this paper were obtained principally from a reconnaissance field survey by the author and from material available in the files of the Wisconsin Crop and Livestock Reporting Service.

In his reconnaissance survey, the author attempted to visit every section (square mile), recording for each a fraction which expressed the character of the slope, the soil, and the cover. Where it was not practicable to visit a section, its character was inferred from that of neighboring sections which had been visited. Less work was done in Bayfield County than in the remainder of the Barrens, since for this county there were available forest and form cover maps of the Land Economic Inventory of Northern Wisconsin. The data contained on these maps were converted into section fractions similar to those used in the author's reconnaissance elsewhere in the sand country. All of the fractions, one for each section (square mile) of the Barrens, were placed on a large map, and from this map the data were obtained for an isopleth map of per cent of land in crops (Figure 4) and for cover charts of each subregion (Figure 5).

The files of the Wisconsin Crop and Livestock Reporting Service contain data as to the number of farms, acreage of farms, acres in different kinds of crops, etc. by civil towns. Unfortunately, many of the civil towns of Northwestern Wisconsin are large (for example, Gordon has an area of 156 square miles) and most of them lie partly inside the Barrens and partly outside. The part outside of the sand country may be an important agricultural region, while that in the sand is almost uninhabited. Under these conditions the large total for a given town will completely obscure the true conditions in the sandy part. The meeting of this difficulty constituted a serious problem.

County Treasurers' offices were visited, and the farm boundaries described in the records were drawn off on specially prepared township plats. This work was facilitated by the fact that there is practically no renting in the Barrens, nearly all the occupied farms being in the hands of their owners. Wherever there were improvements on the land, then it was considered that such land was part of a farm, possibly occupied, and the farm was outlined on the plat and the owner's name printed in. Such farm maps were prepared for every township (36 square miles) or fraction of a township in the Barrens.

The files of the Wisconsin Crop and Livestock Reporting Service contain, in addition to the data by civil towns, similar data for each individual farm under the name of the farmer. This information by farms was copied out for every civil town any part of which extends into the Barrens. No detailed locations within the civil town are given for these farms, but by checking the names of the owners against the farm plats made up from the County Treasurers' records there is a striking uniformity in their appearance and in the farm practices employed. The average farmer owns his farm of approximately 120 acres. The land has been laid out by sections, and a farm is usually some multiple of 20 or 40 acres, and is divided up into rectangular plots. Only 20 per cent of the average farm is cultivated, and only 1.3 per cent of the region as a whole, the remainder being partly timber land and partly land which is uncultivated and untimbered, essentially idle at the present time (Figure 5). A barbed wire fence tacked to the trees may enclose a small part of the uncultivated land, the fenced area serving as pasture for three or four dairy cows during the summer season. The pasturage is poor, however, since sandy soil supports only a thin, unnutritious grass over the open stretches and practically nothing edible in the wood lots. The quack grass meadows which occupy the deserted fields of abandoned farms give better, though by no means ideal, pasturage. During dry summers conditions become particularly bad, since the sand is very liable to drought. Poor grazing is in a measure offset by large pasture acreage per cow. The small, rectangular fields which make up the remainder of the typical farm are unfenced, for land once cleared for crops is never pastured until it is completely abandoned as crop land. Improved pasture and pasture in rotation with crop land are almost unknown in the Northeastern Hill Section or anywhere else in the Barrens.

The keynote of the farm system is dairying, and this theme is borne out in the high per cent of cultivated land given over to such crops as hay, oats, and corn (Figure 5). Thirteen of the twenty-four acres cultivated on the average farm are planted in clover and timothy hay, a crop which is benefited

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it was possible to obtain the names of most of the farmers located in each township or fraction of a township constituting the Barrens. By listing after each farmer's name the number of acres he had in each crop, totals were obtained of the acres in various crops per township or fraction of a township, and the data converted into per cents of total cultivated land in various crops per township. By such a method, if only half of the farms in a given township were listed, the result was still useful since it represented a fair estimate of the proportion of the cultivated land in different crops.

Assemblage of the data thus made available gave, for each subdivision of the Barrens, the average size of farms, the per cent of the average farm in crops, and the relative proportions of the cultivated land given over to the various crops (Figures 2 and 5). Unfortunately, livestock figures are not collected by farms and information on this subject was limited to what could be obtained by personal observation and inquiry.

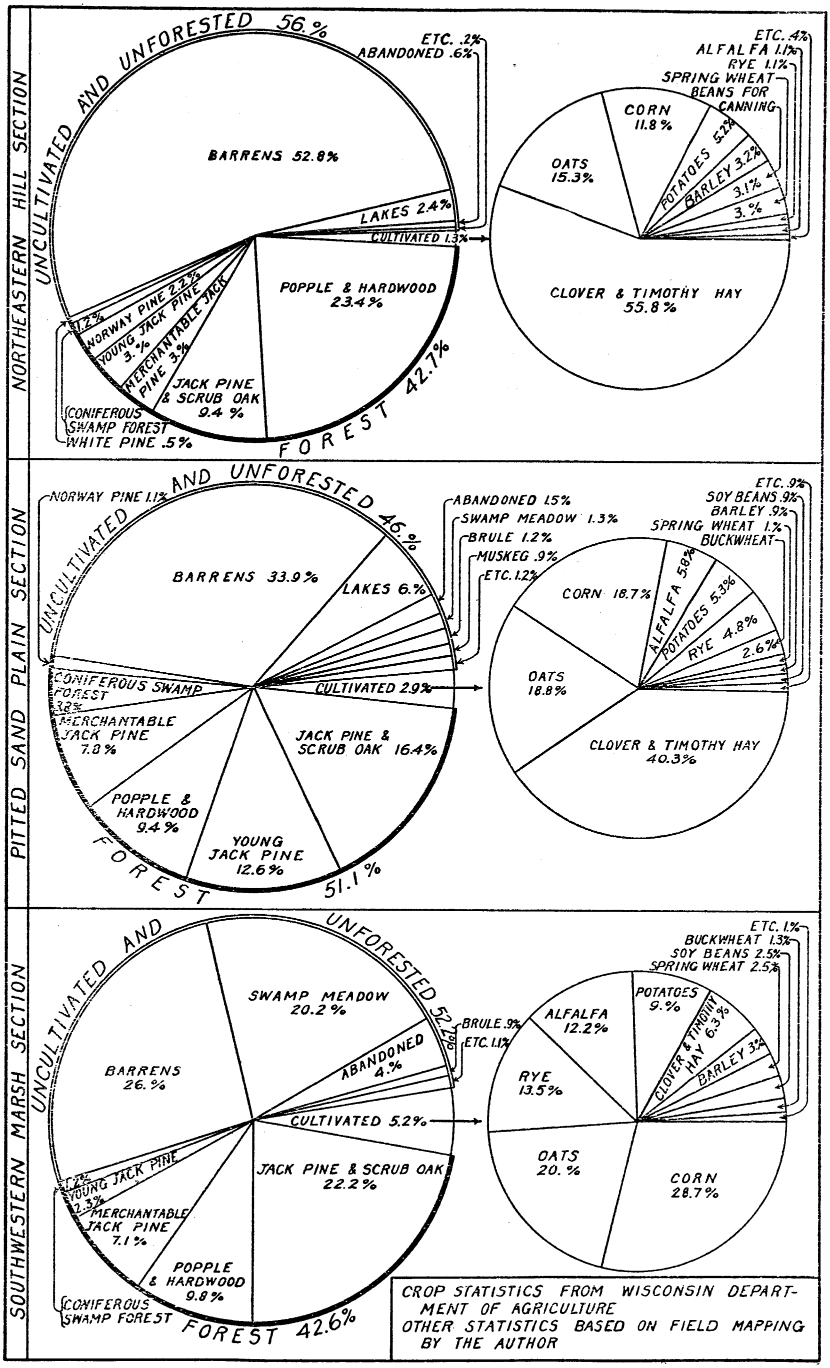
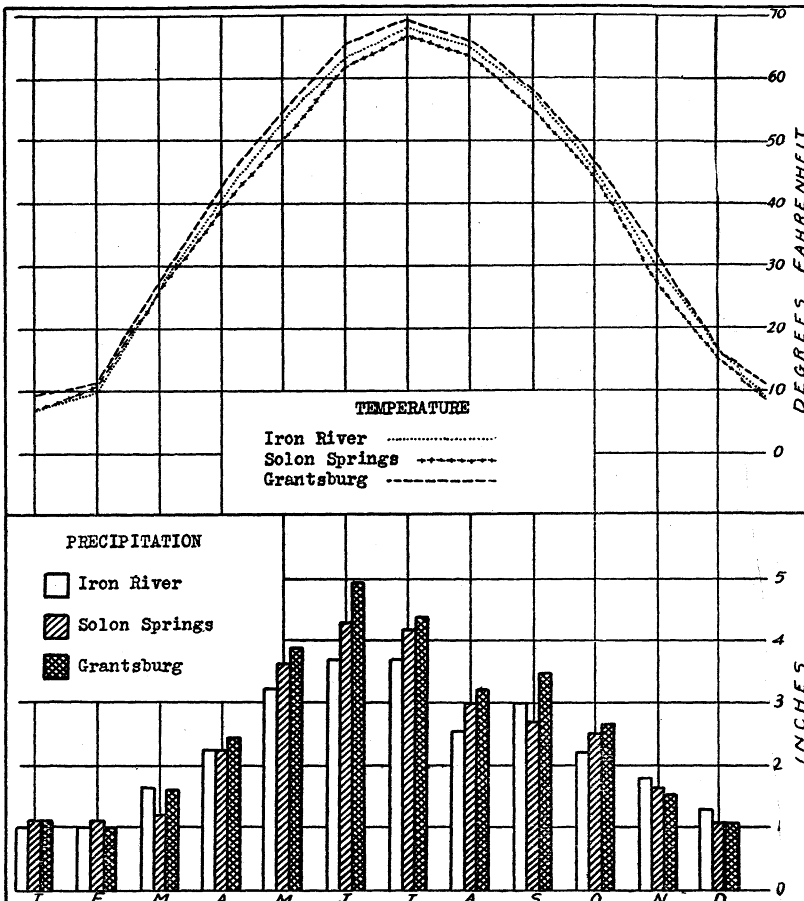


FIGURE. 5. Cover analyses of the three subdivisions of the Northwestern Pine Barrens of Wisconsin.

by the cool summers and adequate summer rainfall typical of this part of the United States (Figure 6). The snowfall, which averages 50 to 60 inches a year, furnishes good winter protection for the crop, but the sandy soils are poor in plant foods and heavy stands of hay are not to be expected even in the most favorable years, while in dry years the droughtiness of the sand asserts itself, making the yields particularly low. Moreover, the soil is so acid that clover can be started only with difficulty unless lime is used, and good stands of clover are correspondingly rare. Since conditions are not ideal for hay, the explanation of the large acreage relative to other crops seems to lie partly in the necessity for a winter feed for dairy cattle in a region where summers are too short and cool to grow good corn even for ensilage, and partly in the location of the sand country in a section of the United States where hay is very generally a well adapted and very important crop.

Approximately 12 per cent of the cultivated land on the average farm is in corn. In this activity the sand farmer enjoys a certain advantage over his neighbor on the adjacent heavier soil areas for sand warms up quickly in the spring and allows earlier plowing and earlier planting of the crop. The corn grown is a quick maturing variety, Northern Yellow Dent or Early Wisconsin Number 25. It is planted during the last week of May, and, although it may be ripened in favorable years, the crop is grown more for its ensilage or fodder value than for grain. Frosts may occur almost any time during the summer and kill or seriously damage the corn. Although this is not a frequent happening, it serves to curtail the acreage planted. The common practice is to cut the corn for ensilage or fodder early in September, or sooner if an unseasonable frost occurs. The portion used for ensilage is limited, as silos are rare in the Northeastern Hill Section. This seems to be due to (1) small bulk of ensilage obtainable from the type of corn that can be grown, (2) danger of the crop's development being cut short by an early frost, and (3) lack of capital on the part of the farmers.

Of the small grains, which occupy 22 per cent of the cultivated land, oats is by far the most important, exceeding corn in total acreage. The cool, fairly moist summers and the poor soils of the Barrens favor a fairly high relative importance of the crop. Barley and spring wheat, which are poorly adapted



Station:	Length of record (years)	Average killing frost dates last	first	Average growing season (days)	Mean annl. pption. (inches)	Mean annl. snowfall (inches)	Mean annl. temp. (degrees)
Iron River	15	May 18	Sept.23	128	28.40	63.5	39.8
Solon Springs	15	May 23	Sept.13	113	28.75	49.8	38.9
Grantsburg	28	May 19	Sept.19	123	31.46	51.7	41.6

Sites: Iron River station in slightly rolling country, on north slope of low hill, elevation 1096. Solon Springs station in St.Croix Valley 1/4th mi. west of Lake St. Croix and 45 to 50 feet above it, elev. 1083. Grantsburg station on level of Barrens, 150 feet from Wood River, elevation 905.

CLIMATIC CHART

FIGURE 6. Climatic conditions in the Northwestern Pine Barrens of Wisconsin. (Based on United States Weather Bureau data.)

to the sandy soils, are of considerably less importance than oats, while fall sown rye, though seemingly better adapted to the soil and climate of the Barrens, occupies less acreage in the Northeastern Hill Section than either barley or spring wheat.

Potatoes is the only crop very generally grown in the Northeastern Hill Section which does not play a part in dairying. The acre or two of this vegetable to be seen near the house on almost every farm are for the home table. The cool and fairly moist summers and the light soil would seem to furnish ideal conditions for potato production, but in reality the soil is too light and lacks a sufficient supply of plant foods. Hence, there is little commercial potato growing.

The hay and grain crops follow a rude rotation, but it is ordinarily not very systematic, and there is no generally accepted system of rotation for the whole region. Animal manures are used to some extent. Green manuring is rare. Instead of the use of scientific farm practices to combat handicaps of soil and climate, the common practice seems to consist of meeting declining yields by cutting down acreage until returns are not enough to pay the taxes on the land, and the county must take possession.

The houses and barns on the Barrens farms are by no means pretentious. The houses are usually small, two or three room structures, frequently either log cabins or tar paper covered frame buildings. The log cabins are relics of the days of heavier forests, and none are being built now — in fact, few houses of any sort are being built since settlers are leaving the Barrens rather than moving in. The more recently constructed buildings are of frame, frequently little more than shacks, covered with black or brown tar paper which helps to protect the inmates from the winter cold in a region where the average January temperature is 7° Fahrenheit (Figure 6). There are no well kept or regularly laid out yards about the houses, although a few jack pine are frequently left standing as shade and a partial wind break. Planted trees are seldom to be seen, and orchards are strikingly absent, since frost may visit the region almost any month in the year.

The barns are small log or frame buildings, unpainted, but frequently supported by stone or concrete basements which serve as winter quarters for the cattle, the horses, and the 20 or 30 chickens which make up the farm livestock. Large barns are not needed as the livestock population is small, and the amount of hay and grain to be stored is not great. An old Ford car standing near the barn is a critical part of the scene, since it plays an important role in the dairy industry as it is carried on in the Barrens. Milk is separated and occasionally, perhaps twice a week, sour cream is taken by car to the Iron River or Benoit creameries, or to some railroad station for shipment to Duluth, Superior or Ashland. Sweet cream brings a better price than the sour product, but the distance to the creamery is too great to haul daily the small amount of cream which the farming operations yield, and the farms are too scattered for creamery trucks to make profitable collecting trips.

A farm water supply is obtainable here and farther southwest in the Barrens at a depth of 50 feet or less, but the wells are likely to go dry during a dry summer. Most farms have pumps, only a few of the more prosperous farmsteads including a windmill in their equipment. The house and barn, a few jack pines left near the house, a pump, a small unfenced garden — these constitute the average farmstead.

The Vilas Hill Country

Nearly three-fourths of the Northeastern Hill Section is included in the Vilas Hill Country, a region so rugged and stony in comparison with the flat sandy benches, that the Wisconsin Soil Survey has given it a separate soil classification[12] (Figures 2 and 3). In this hill country numerous depressions, some dry and grassy, and others occupied by small lakes or lake remnants, alternate with sharp hills or knobs in a relief reaching 100 to 150 feet (Pl. I, fig. 1). Forests and barrens dominate the landscape, the former particularly in the southwest, while a nearly continuous sweep of barrens covers the northeastern part. The one really good road which crosses the hill country, the Superior-Ashland Highway, curves and twists over one of the most wildly picturesque parts of this rugged area, while the few secondary roads wind grotesquely around hills and depressions, a condition strangely at variance with the usual rectangular pattern found elsewhere (Figure 7). Narrow roads, scarcely more than two ruts straddling a grassy ridge, meander

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[12] Musbach, F. L., et. al., Reconnaissance Soil Survey of North Part of North Western Wisconsin, Wisconsin Geological and Natural History Survey, Soil Series 6, Bulletin 32, pp. 30-32, 1914.

far into the hills to isolated farms which correspond in most respects to the typical Northeastern Hill Section farm already described. There is, however, a greater dominance of clover and timothy hay over other crops than was true of the typical farm (Figure 5), a condition which seems to be attributable in part to the rough topography. The distance to market is so great for one or two of the farms, that it is necessary to convert cream into home-made butter, a more compact product which keeps better.

The Vilas Barrens. The whole northeastern part of the Vilas Hill Country (Figure 2) is a barren, monotonous sweep of sweet fern and mixed popple[13] and hardwood brush with rare clusters of jack or Norway pines, the only indication of a former forest cover. Streams are absent from this barren, hilly country, and even lakes are scarce, drainage being entirely by seepage into the sands and by evaporation. The Superior-Ashland branch of the Northern Pacific Railroad crosses the Vilas Barrens just east of Iron River, but it is only a "bridge" crossing, with little or no traffic to be picked up. Formerly the "Battle Axe" Division of the Northern Pacific, connecting the village of Iron River with Washburn, crossed the northern part of the area, but with the passing of logging days the road with its many miles in sand became a burden, and service has been discontinued and the rails removed.

Poor though the soil is, it is capable of producing good stands of jack and Norway pine and even fair stands of white pine,[14] and plans are being made to reforest this district during the next fifteen or twenty years, with the aim of bringing the land back to the point where it will be an asset.[15] To this end, much of the land, which because of tax delinquency reverted to Bayfield County, has been sold to the United States Government for a National Forest. Part of the land within the boundaries of

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[13] The term "popple" has come into general use in Northern Wisconsin for second growth forest where aspen is dominant. See, for example, usage in: Land Economic Inventory of Northern Wisconsin, Wisconsin Department of Agriculture and Markets in co-operation with the Geological and Natural History Survey and the Conservation Commission, Bulletin 100, 1929.

[14] Bordner, J. S., and Morris, Wm. W., in Land Economic Inventory of Northern Wisconsin, by Whitson, A. R., et. al., Wisconsin Department of Agriculture and Markets in co-operation with the Geological and Natural History Survey and the Conservation Commission, Bulletin 100, pp. 54-61, 1929.

[15] Bean, Leslie, Acting for S. D. Anderson, Forest Supervisor, Park Falls, Wisconsin, Private Communication, February, 1930.

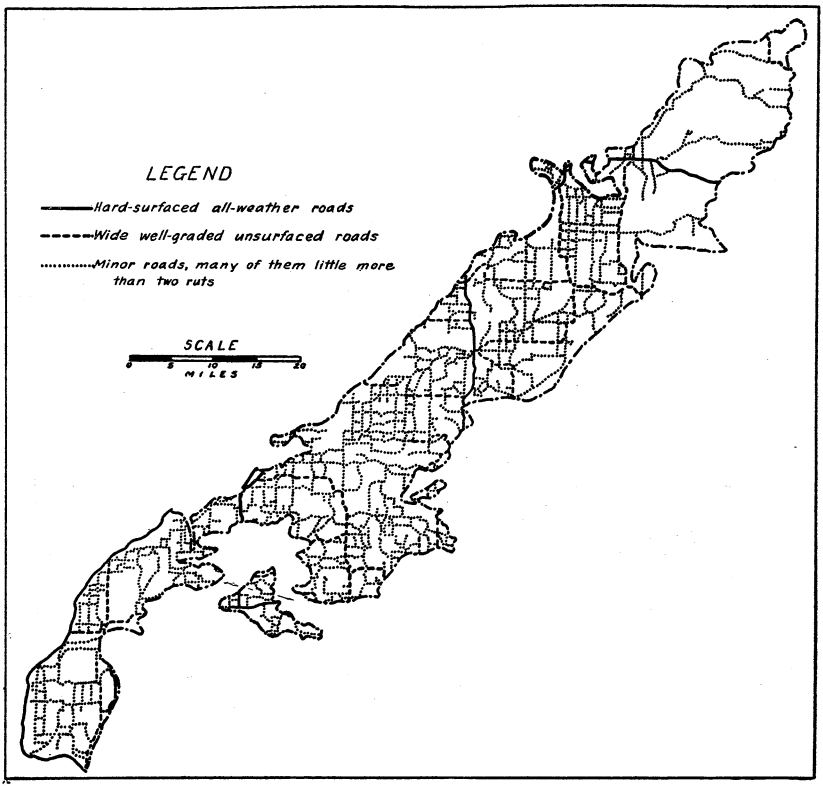

FIGURE 7. Roads of the Northwestern Pine Barrens of Wisconsin, 1929. (Based on various existing road maps and on field observations by the author.)

the projected forest is still privately owned, but is gradually being bought up at prices ranging from $1.25 to $1.85 per acre. Two widely separated fire towers have been established so that vigil may be kept against fire, which originally reduced the land to its barrens condition, and will be a constant menace toward reforestation in the future.

The Southwestern Vilas Area. At the southwestern end of the Vilas Hill Country (Figure 2) there is a hilly area which is like the Vilas Barrens in topography, but has a much heavier forest cover. There are some bald, barren patches it is true, but forest dominates — a typical second growth forest in which popple and hardwoods play a prominent part, while jack and Norway pines are of relatively minor importance. Unfortunately, most of the popple and hardwood is of little use, but a small amount of jack pine is being cut here and there for boltwood which is shipped from Iron River.

The Lake Belt. Between the Vilas Barrens and the Southwestern Vilas Area there is a belt extending southeastward from the village of Iron River (Figures 1 and 2) in which lakes are fairly numerous (Figure 8). The larger lakes are connected and drained by White River, which flows out into the clay area to the southeast. This stream, together with one or two others in the Lake Belt, are the only streams in the entire Northeastern Hill Section.

Wiehe, Basswood, Iron, and other lakes of this belt are receiving a steadily increasing number of summer visitors, and

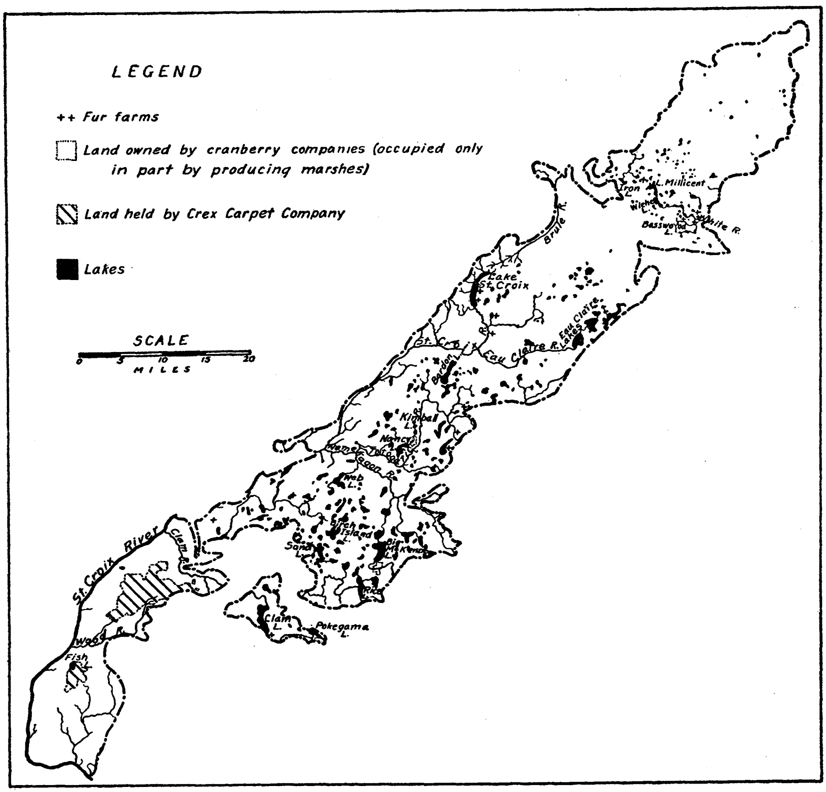

FIGURE 8. Streams and lakes, fur farms, cranberry marshes, and Crex meadows—Northwestern Pine Barrens of Wisconsin, 1929. (Data from various sources including field mapping by the author.)

summer homes and resorts are becoming prominent features of the landscape. The summer resort industry is by far the most important utilization of the Lake Belt. Lakes in the sand country are clear, have good sand beaches for bathing, and, except where they have been over exploited, are well stocked with fish. Deer are plentiful and hunters have long made regular winter visits to the region.

An area with as many lakes and marshes as the Lake Belt might be expected to possess some fur-bearing animals, so it is not surprising to find a few commercial fur farms. Of the five fur farms[16] on record in the area one is devoted to silver fox rearing, one to beaver, two to beaver and muskrat, and the fifth is licensed to grow "muskrat, mink, skunk, marten and raccoon" (Figure 8). On at least two of these farms and probably on others chinchilla rabbits are reared as a sideline.

Two advantages enjoyed by all the fur producers in this area are a good fur-producing climate and cheap land. Cool summers and cold winters favor good fur development, while land values of five to ten dollars per acre mean a smaller investment than would be necessary in better soil areas.

The silver fox farm is located in the interior of 80 acres of forest, secluded from the prying eyes of chance sightseers. Here, a high woven-wire fence encloses a typical fox farm layout of pens and kennels, where 20 silver foxes are housed. The rather sparse stand of mixed jack pine, popple, and hardwood of this section of the Barrens permits the penetration of enough sunlight to disinfect the ground and pens, while giving spots of shade large enough to provide rest places for the animals. The sandy soil is both an advantage and a disadvantage. For sanitary reasons a well-drained soil is desired and sand amply fulfills this need, but foxes can burrow to a depth of several feet in sand, so fences must be extended three feet or more into the ground, a proceeding which increases the cost of fencing considerably. A fairly deep winter snow cover, such as is enjoyed by this general region, is said to help control most of the common parasites which give trouble in fox rearing.

The other fur farms range in size from 7 to 30 acres. Just outside the village of Delta is a beaver and rabbit farm which is fairly representative. The beaver pond, about one-eighth mile

[16] Data for all except the fox farm collected from files of Conservation Commission of Wisconsin.

in diameter, has been enclosed by a woven-wire fence, and now a beaver house rises above the water level, while along the shore of the pond popple stumps are all that remain of a once vigorous second growth timber. A pile of untrimmed young popples just inside the fence represents the rations of two dozen beavers for the coming night.

The raising of rabbits for fur and meat is of as great importance as the raising of beavers on the fur farm near Delta, a large gray and white rabbit barn with associated fenced yards being the home of 150 chinchilla rabbits. The region has no special advantages for the rearing of these animals, but this work fits in so well with other fur farm activities that it is engaged in by nearly all the fur farmers of the Barrens. Indeed, some of the small scale dairy farmers are beginning the rearing of rabbits as a minor source of income.

Detailed information is not available as to the average total value of output of the fur farms, and indeed such a figure would be of little significance for production is quite irregular and may consist either of live animals for breeding purposes or of pelts. For instance, one farm sold 6 live beavers in 1929, another sold nothing but pelts (2 mink, 2 raccoon, and 15 muskrat), while a third reports 8 muskrat hides sold. Most of the farms are too new to have much of a salable surplus as yet.

The Lake Belt is traversed by the Duluth, South Shore, and Atlantic Railroad, which serves particularly the resorts on the lakes, and has been partly responsible for the development of the resort industry. A village serves each end of the Belt, and adjacent to each the resorts are well developed and roads are fairly numerous, while an intermediate area shows considerably less development. Delta, a village of 12 people, has a store and post office combined, and is a station on the railroad (Figure 1). Although it is located in the Barrens and although it serves the resorts of the Lake Belt, Delta looks east for most of its trade, depending primarily upon the agricultural section in the Superior Lowland. The other end of the Lake Belt is served by Iron River. This village of 800 people is really located on the Plainfield Terrace which borders the hill country to the northwest, and is of interest here chiefly because it serves the resorts of the Lake Belt and has made possible the considerable commercial development of this section.

The Plainfield Terraces

The Superior-Ashland highway enters the Northeastern Hill Section about three miles west of the village of Iron River. For 6 miles east of its point of entry into the Barrens it traverses a high, flat, sandy bench land before finally rising into the hill country to the east. At the village of Iron River an old road may be followed which runs a short distance north and then almost straight northeast away from the main highway. For six miles or more the road is almost perfectly level, running as it does on a northeastern extension of the same terrace or bench land observable at Iron River. Sweet fern and scrub oak barrens alternate with smaller patches of jack pine forest, while not a farm is encountered in spite of the fact that the village of Iron River is but a few miles distant. To the northwest the land surface drops off to the heavier clay areas of the Lake Superior Lowland, where hardwood and popple forest are interrupted by many farms with cleared fields and large red barns (Figure 2). To the southeast of the bench there is an abrupt rise to the hummocky hill country, which constitutes the heart of the Northeastern Hill Section. This bench land described is one of the two Plainfield terraces which fringe the hilly part of the Northeastern Hill Section (Figure 3).

Sixty-five per cent of the total area of the Plainfield Terraces is unforested and uncultivated land, while 95 per cent of the land thus classified is barrens, an expanse of sweet fern, scrub oak, and pin cherry with occasional isolated jack pines. Abandoned farms make up about 2 per cent of the uncultivated and unforested area. Usually fire has followed, or may even have played a part in, the abandonment, and today only the charred remains of a board or two, a few stones, and a quack grass meadow mark the former farm site.

Jack pine, either alone or mixed with scrub oak, is the dominant forest type, but less than 15 per cent of the timbered land is in jack pine large enough to be cut for pulpwood.

Two and one-half per cent of the Plainfield Terrace land is cultivated. The slightly higher per cent of the cultivated land here than is found in the Vilas Hill Country (Figure 4) seems to be due not so much to topographic differences as to the location of the terrace lands marginal to better soil areas and to the presence of the village of Iron River in the southwestern part of the northwestern terrace. This village, though depending largely upon the better soil areas to the north, has been responsible for a higher degree of agricultural utilization of adjacent parts of the Plainfield Terrace than is normal to the region.

The village of Iron River developed at a point where the Northern Pacific Railroad crosses the Duluth, South Shore, and Atlantic, a point almost equally distant from Superior and Ashland. The first house of the village was built in 1885. First the headquarters for settlers who were attracted by government timber lands thrown open for settlement in the Vilas Hill Country to the east and northeast, it became later an important saw mill town. In 1892 it suffered the fate of many of the early saw mill towns in being burned to the ground, but was built up again shortly after. A small stream fed by lakes to the south and flowing northward through Iron River has sometimes been used to generate a little power, but this has at no time been an important factor in the growth of the village. The same stream was used to float a few logs in saw mill days, but even then was unimportant. Iron River village long ago ceased to be significant as a lumber milling center though even now a small mill is operated by the local lumber yard.

The village of Iron River, with a population of about 800, is now in the peculiar position of being located on a strip of Plainfield Terrace, while it depends for its livelihood almost entirely upon areas lying on either side of this terrace. Farmers from adjacent parts of the Lake Superior Lowland to the north bring to Iron River almost all of its farming trade, and they furnish the village creamery with most of its cream supply. The local cheese factory, requiring a large quantity of milk near at hand, is located out in the Lake Superior Lowland about 3 miles north of Iron River, and draws none of its raw material from the Barrens. A bean canning factory, located at the edge of the village, is another plant which looks for most of its raw material to the better soil areas to the north. A few bean fields occur on the sand, it is true, fields which are dotted with pickers in late August, but the wax and string beans which are canned do better on soils that are heavier than the sands of the bench. Iron River takes great pride in its summer resort trade and in the many lakes and resorts which are tributary to the village, but here again the Plainfield terrace upon which the village itself is located is unimportant as most of the lakes and resorts are in the Lake Belt of the Vilas Hill Country to the south. From this same belt, too, come most of the jack pine logs which are shipped from Iron River station. Thus in every activity upon which the village is dependent the Plainfield Terrace land plays but a minor role.

THE PITTED SAND PLAIN SECTION

A few miles southwest of the village of Iron River a ridge of stony loam soil projects from the northwest, narrowing the Barrens at this point to a scant six miles. At this constriction the rugged topography of the Northeastern Hill Section terminates abruptly, and a sand plain, locally pitted, stretches away to the southwest (Figure 2). The surface of the plain slopes gently in the same direction, so gently, in fact, that from almost any point of observation an impression of flatness is obtained.

Jack pine forests, frequently with some admixture of scrub oak, share the Pitted Sand Plain Section almost equally with sweet fern and grassy barrens (Figure 5). Stunted oak bushes and occasional isolated jack or Norway pines dot the barren tracts. The northeastern end of the area is predominantly forest; in other localities, as southwest of Gordon, there are large bald or barren spots. More common still, for the section as a whole, is an intermingling of barren and timbered stretches with sporadic patches of brule, or burned over land, the intermediate stage between forest and barrens. The widely scattered farms are minor but important features of the landscape.

The general level of the plain, intact over large areas, is surprisingly pitted in others (Pl. I, fig. 2) and in many of these depressions lakes are found. Some lakes are isolated, others are in clusters, and, though they are very generally scattered, there is a noticeable tendency toward an increase in number from northeast to southwest throughout the section (Figure 8). So numerous are the pits in many parts of the Pitted Sand Plain that the topography might almost be described as hill country of mild relief. Popple, birch, and an occasional white pine fringe the shores of the lakes. The presence of these species may be simply a response to a high ground water table in the bottoms of the depressions, or there may actually be more fertile soils and soils of higher water holding capacity in these hollows due to the washing in of silt by surface water. The shores of the most attractive lakes are used in part by summer homes and resorts, but many lakes are partially filled, with swampy edges, and here and there depressions have been filled to the point that they have become all swamp, covered with a coniferous forest of tamarack and spruce except where logging or fire has reduced the area to swamp meadow, muskeg, or alder.

The general surface of the Pitted Sand Plain is cut also by several river valleys (Figure 8). The St. Croix and Brule rivers occupy a single steep-walled valley, one of the outlets of former Lake Duluth — a trough nowhere over two miles wide, with a low col between the headwaters of the two streams. The narrowness of the portage from the St. Croix to the Bois Brule just above Lake St. Croix made this at one time an important highway of communication between Lake Superior and the Mississippi River. It was so familiar to the Indians that the earliest white explorers learned of it, and utilized it to a considerable extent. Du Luth crossed this portage in 1680, Carver traveled that way in 1767, Le Sueur in 1793, and Schoolcraft in 1832. At one time it was even planned to build a canal along the St. Croix-Brule route, but this was never attempted.[17]

The Brule-St. Croix Valley stands out not only as a trough in the flat surface of the Barrens, but for a distinctive vegetation grouping as well. Evergreen swamp forest, swamp meadow, muskeg, white and Norway pine, hardwoods, and popple are all represented, but the jack pine and scrub oak, so typical of the upland, are entirely lacking. Peat and loam soils share the Brule-St. Croix bottom land, and it is to these soils that the distinctive vegetation is due.[18] Lake St. Croix, the largest lake of the Northwestern Pine Barrens, lies in this valley, its shores being utilized for summer homes and resorts, particularly on the west or Solon Springs side (Figure 1). The Minneapolis, St. Paul, and Sault Ste. Marie Railroad follows the valley from Solon Springs to Gordon, both villages being located in the bottom land. Aside from these two villages,

[17] Martin, Lawrence, The Physical Geography of Wisconsin, Wis. Geol. and Natl. History Survey, Bulletin 36, p. 387, 1916.

[18] The soils and vegetation of the bottom lands are so unlike those normal to the Barrens that only those portions having true Barrens country on either side have been included in this study.

which are affiliated more with the Barrens proper than with the valley, evidences of utilization are restricted to a few scattered sportsmen's lodges along the St. Croix and to a number of beautiful summer homes along the Brule, all of which capitalize their forest surroundings and are unaccompanied by any considerable clearings. The Brule is a trout stream, particularly in its lower reaches, and many fishermen work its rapid waters during the summer, both in the Lake Superior Lowland and farther upstream in the Barrens. A State Fish Hatchery is located on a branch of the Brule between Winnebijou and the village of Brule at a point within the boundaries of the Sand Barrens.

The Nemakagon, the Yellow, the Totogatic, and the Eau Claire rivers, as well as smaller streams tributary to the St. Croix, flow in shallow grooves in the surface of the Pitted Sand Plain. These streams carry the overflow of numerous lakes, but a surprising number of lakes are without surface outlets. The northeastern end of the Pitted Sand Plain has large tracts without a single stream, where drainage is entirely by evaporation and seepage into the sands.

The gently inclined Pitted Sand Plain is interrupted by elevations as well as depressions — elevations which stand out above the surrounding plain as stony islands in a sea of sand. Three islands of Chelsea Loam (Figure 3), one lying just to the north and the other two just to the west of the Eau Claire Lakes, average two miles in diameter and stand out from the surrounding sand country not only because of their higher topographic position, but also because of heavy stony soils and a vegetation consisting largely of popple and hardwoods. Although they are more fertile than the sand areas, the hilly character of these spots of Chelsea Loam, the difficulty of clearing them of vegetation, and their possession of numerous swampy depressions have repelled settlers, and they are today practically unutilized.

In the southwestern part of the Pitted Sand Plain the gentle southwestward slope of the Barrens surface is interrupted by a narrow belt of hill country which stretches from the vicinity of Web Lake to the eastern edge of the Barrens. In relief and ruggedness this area is comparable to the Vilas Hill Country of the Northeastern Hill Section with which it corresponds in soil type with the difference that in the more southwesterly area the hills are flat topped. The shape of this belt suggests terminal moraine, the original rounded knobs of which may have been planed down by the waves of a large marginal lake thought to have occupied this area at one time.[19] This hilly belt differs little from the surrounding Plainfield Sand country in its natural and cultural forms, jack pine forests and barrens alternating here as elsewhere, with farms few and scattered.

At the southwestern end of the Pitted Sand Plain heavier soils completely isolate about thirty square miles of sand country. Not only in soils, but in vegetation and utilization as well, this isolated area is a part of the Barrens, and is included as such in the following pages without further reference to its isolated character. In this same area irregularly shaped peninsulas of better soil, with popple and hardwood vegetation and considerable agricultural utilization project into the Barrens, giving to this portion a highly irregular outline, while frequently no topographic break marks the edge of the Barrens, but rather a gradual soil, vegetation, and utilization change.

Just east of Clam River (Figure 8) there is a southward projecting tongue of Chelsea Loam which stands out in sharp contrast to the neighboring Barrens, and is a prominent feature of the area. It is a distinct ridge in form, averaging one-fourth to one-half mile in width and standing 70 feet above its surroundings with a dense scrub oak and popple cover clearly at variance with the jack pine, scrub oak, and sweet fern association of the Barrens.

The Pitted Sand Plain with its depressions and elevations, its forests and barrens, its summer resorts and scattered isolated farms, is welded together by a road system which is very elaborate for such a little used area (Figure 7). Passable roads are easy to clear and to maintain in the sand country. This is particularly true in the flattest areas and in such parts secondary roads mark every section line, roads which may not be used more than once a month, but which are traversable nevertheless. Rectangularity characterizes the pattern, though locally lakes force the roads to curve, and some few show absolute disregard for section lines in following the shortest possible courses to their destinations. Even in the hillier sections where rougher

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[19] Hansell, J. M., The Glacial Geology of an Area in the Northwest Corner of Wisconsin, Unpublished Ph. D. Thesis, University of Wisconsin, 1930.

topography would dictate the more careful selection of a course, the two-rut secondary roads so characteristic of the Barrens tend to run straight, disregarding grades.

As might be expected, few of the roads are well built or well kept. The common two-rut roads are tributary to graded sand roads, while these in turn are tributary to the one or two surfaced highways of the area. Of the latter character is the north-south highway through Solon Springs, Gordon, and Wascott, the only towns of the Pitted Sand Plain. Nearly all road surfacing material must be brought into the Barrens. Glacial gravel deposits are available in the heavier soil areas to the north and south, but only one commercial gravel occurrence has been reported from within the Barrens. This deposit, lying along the main highway about a mile north of Gordon, is apparently a stream deposit. It has been developed and some of the gravel used on the adjacent road. Two railroads parallel the north-south highway and connect the same series of towns, Solon Springs, Gordon and Wascott, and these railroads, together with the highway, make up a strip which is the commercial axis of the Pitted Sand Plain Section.

There is no regional concentration of the principal landscape forms presented by the Pitted Sand Plain. Thus, no one area can be laid off as lake country, for lakes are widely scattered over the entire region. Every township has timber land, every township has barrens, and no township is entirely without cultivated land. In an area with so little basis for regional subdivision landscape types must supercede the region or subregion as the unit for discussion. In the Pitted Sand Plain five landscape forms — forests, grassy and sweet fern barrens, cultivated land, lakes and their shores, and villages — recur so frequently as to justify detailed consideration as types.

The Forests

Forests occupy about one-half of the Pitted Sand Plain. One-third of the timber is jack pine of all sizes intermingled with small scrub oak (Figure 5). One-fourth of the forested area is occupied by dense, pure stands of young jack pine, while 15 per cent is occupied by jack pine which is sufficiently mature for use as pulpwood. Popple and hardwood (18 per cent of the total forested area) and coniferous swamp forest (7.5 per cent) are the only other important components of the forest, although there are a few scattered forties[20] of Norway pine. Of these various kinds of forest the swamp growth and the popple and hardwoods are restricted and localized, and do not play a prominent part in the typical forest of the section.

Particular interest attaches to the jack pine because through its utility as pulpwood it forms the basis of the only woodworking industry of the Barrens. A few Norway pines are marketed with the jack pine bolts as pulpwood, but the companies much prefer jack pine for this purpose. Only those trees which will produce bolts 8 feet long with a minimum diameter of 4 inches are usable. Although particularly abundant in the northeastern part of the Pitted Sand Plain, forties of jack pine of merchantable or pulpwood size are also found generally scattered over the southern end as well as to a minor extent elsewhere. Frequently, too, areas of mixed jack pine and scrub oak contain jack pine which though scattered is large enough for use.

The more accessible jack pine of pulpwood size has been cut, so the traveler along the better roads of the Pitted Sand Plain Section sees at first little field evidence of the industry. Then, from some obscure side road a truck will come lumbering onto the highway, a truck loaded with peeled 8-foot jack pine bolts of diameters of 4 inches and up, piled crosswise. If followed, the destination of the load will be found to be Gordon, Solon Springs, or some other point on the railroad where long piles of these logs are stacked. Along back roads of the section an occasional glimpse may be caught of a distant hillside where newly peeled bolts, scattered or piled, await their turn to be hauled to the railroad. The well traveled condition of some of the back roads in such a poorly settled region is a further reflection of the pulpwood industry.

It is customary for the large pulpwood companies operating in the area, the Cornell Wood Products Corporation, the Nekoosa Edwards Company or others, to place their orders for pulpwood with buyers at the local villages either direct or through a jobber. The buyer travels the many secondary roads

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[20] The term "forty" is used throughout this paper to refer to the forty-acre tracts which are normal units in any area where the section-township-range system has been used.

of the area looking for available pulp timber and contracting with the owner of such timber for stumpage rights or the right to cut the jack pine of pulpwood size. During the summer the buyer sends out a crew of workmen who camp where the cutting is to be done. White men are commonly engaged for this work, but sometimes, as near Danbury in the western end of the section, Indians are hired to do the work. The workmen cut and trim the trees and usually peel them. Then trucks come and the bolts are loaded and hauled away.

It might be expected that the jack pine cutting would be a winter industry as the cutting of saw logs in this country was, but such is not the case. Winter operations were required for the ordinary lumbering, particularly in swamp areas, since transportation was impossible in such regions in summer, but jack pine does not grow in swamps, and is accessible at all times of the year. It is natural, therefore, that it should be cut in the summer when working conditions are good and labor efficient, rather than in winter with its hampering snows and low temperatures. Another factor in the situation is that all the jack pine must be peeled before being used, and while this operation was formerly performed at the mills, in recent years the tendency has been more and more toward sap-peeling before shipping. The sap-peeling season for jack pine is during the late spring and early summer months. The most successful way to remove the bark is to strip it from the tree in the field during this sap season immediately after the timber is felled, and this is now the common practice. Some winter cutting is done, but it is usually minor compared to that of the summer, and is more likely to be the individual effort of some farmer in his lax season than the organized cutting of the pulpwood from a considerable tract. When cut in winter, the bolts are commonly sold unpeeled and in this case the peeling must be done after the bolts reach the mills.

The advantages of removing the bark just as the trees are cut are various. The bark must be removed eventually, and it is most easily done just as the trees are freshly cut during the sap season. The immediate removal of the bark lessens the chance of decay of the log, or of its being attacked by insects which the bark of the dry log harbors. More important still is the fact that the peeled logs weigh less, and the aggregate saving in hauling and shipping is considerable. Notwithstanding these advantages of the peeled product a considerable number of bolts are still marketed unpeeled, chiefly bolts which are cut outside of the sap-peeling season as well as some that are in demand by companies who have machinery for peeling at the mills and do not wish to change their methods.

The various companies which buy jack pine from the buyer, either direct or through a jobber, lease land at railroad stops to pile the bolts until they are needed at the mills at Nekoosa, Cornell, Mosinee, or elsewhere. Long piles of these bolts, both peeled and unpeeled, are to be seen at almost every station or siding in the Barrens (Figure 1). That the mills which use these bolts are all located outside of the Northeastern Pine Barrens is not surprising since these mills use other kinds of wood as well as jack pine, and have other sources even for the latter. For example, the Nekoosa Edwards Company buys spruce, balsam, hemlock, and jack pine.[21] The spruce, balsam, and hemlock are obtained from areas of loam or heavier soils. The jack pine comes from sand areas, 40 per cent of the 30,000 cords which the company purchased in 1929 coming from the Northwestern Pine Barrens, the remainder from the sand area of Central Wisconsin. Since this company is one of the two or three largest buyers of jack pine in the Barrens, these figures serve to give some idea as to the size of the industry. The minor position of jack pine in the list of raw materials which are used suggests the secondary importance of this type of wood even to the principal users. Kraft paper, a heavy wrapping paper, is the principal product made from jack pine by the Nekoosa Edwards Company, while wall board is the chief Cornell product from this material. It is significant that other species of wood are satisfactory for the making of these products, and that jack pine is used principally because it is the cheapest of the several species which might be used.

The quantity of jack pine of pulpwood size which still remains in the Barrens is not great. Younger trees will mature in time, but that will hardly be soon enough to satisfy the demands of the pulp companies. One of these, the Cornell Wood Products Corporation, owns a number of forties of timber land in the

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[21] This information and the figures which follow are from a private communication from the Nekoosa Edwards Company.

Barrens, from which they are not cutting jack pine at present. Instead, these tracts, some of which are clothed with young jack pine, some jack pine of pulpwood size, are being kept for the future when pulpwood becomes scarcer than it is at present.

Almost every year forest fires sweep sections of the Barrens, leaving their record in ghost-like dead trees, or, if several fires have occurred, barren tracts dotted with charred stumps. The fire problem is a serious one here as there is little cultivated land to break the sweep of a fire once started, and the sweet fern of the Barrens, as well as the jack pine, carries fire well. A spark from a locomotive, a burning brush heap, or a camp fire out of control — these are the beginnings of many fires.

In most areas the fire hazard is greatest in May and October. In the Barrens, May is by far the worst of these two, since in the fall the sweet fern is still green and the scrub oak still has its leaves. In the spring, on the other hand, the oak leaves are on the ground and the sweet fern is dry and brown — an ideal bed in which a fire may travel.

Various means are used to combat fires. Along all the roads signs are posted warning the casual camper, and urging the settlers that no brush be burned in May and that none be burned at any time without a permit. Plowed fire breaks are little used, but some of the wide graded roads such as the one running east from Gordon make good fire breaks.

A forest protection system with lookout towers (seven in the Pitted Sand Plain Section of the Barrens), state owned telephone lines, and a regular fire fighting force is in operation. During the spring, summer, and fall there is a man in each lookout tower all day, ready to telephone to headquarters at Brule or Spooner at the first sign of a fire. The many passable secondary roads make it possible for the fire fighting forces to easily reach even the most isolated spots in this little-settled country. The Cornell Wood Products Corporation, owning as they do considerable areas of timber, are especially interested in fire protection, and furnish two men who work under the State Forest Protection service.

Not infrequently a smoke haze hangs over the country on a quiet spring or summer day. It is at such a time as this that watchfulness is at its greatest height. Unfortunately, too, at the same time, visibility from the towers is poor. A telephone message may come in from some distant farmer who is worried because of the smoke haze, and thinks he sees thicker smoke at some spot in the distance. A man from the District office rushes out by car to investigate. At such a time nothing can be overlooked since a fire once well under way may cost thousands of dollars and deface many miles of country.

The Barrens

About one-third of the Pitted Sand Plain Section is grassy or sweet fern barrens (Pl. I, fig. 2). Scrub oak bushes are fairly numerous in some of this type of country and a few jack pines or a Norway pine or two may normally be seen on the horizon. Patches of barrens occur in almost all parts of the Pitted Sand Plain Section, while locally there are stretches of half a township or more almost all of which may be thus classified.

Most of this type is almost entirely unutilized, as its name suggests, but there is one product of value which typically occurs on the barren tracts, the blueberry. This plant does well on acid soils such as those of the Barrens, and in the areas where fire has destroyed the forests it finds a home, the blueberry being almost as characteristic as sweet fern in many of the open areas.

Many blueberry pickers invade the Barrens in midsummer in years when the crop is good, dotting the best berry areas at such times. Some of the pickers come from outside the Barrens, from Superior and other nearby towns, returning to their homes after a single day's outing. Others, often local people, make more of a business of the blueberry picking, selling their product to the stores at Danbury, Gordon, or other local villages. Many of these pickers are Indians. A few live in the Barrens or just outside its edges (as at Danbury), but more come into the area to camp during the blueberry picking season. A late frost reduces or entirely destroys the crop some years, and then the Indian blueberry pickers must go to other areas where the crop is better.

No figures are available as to the total value of blueberries exported from the Barrens, but in good years the quantity sent from some of the towns is undoubtedly considerable.

The Cultivated Land

Cultivated tracts are scattered widely but thinly over the section, amounting to about 3 per cent of the total area. Commonly all the cultivated land on a single farm is contiguous, so each separate cultivated tract means a separate farm and has its separate farmstead. The farms of the Pitted Sand Plain Section average 140 acres in size or somewhat larger than those of the Northeastern Hill Section.

The cultivated area, making up about 20 per cent of the average farm, is usually rectangular in shape, and is in turn subdivided into a number of smaller rectangles of various crops. The crops grown are much the same as in the more northeasterly section, but there is a difference in emphasis (Figures 5 and 9). In the Northeastern Hill Section the hay acreage everywhere exceeded the acreage of total grains; in the Pitted Sand Plain they battle on fairly even terms with a tendency toward supremacy of the grains in the southwest. This seems to indicate more intensive dairying here than in the Northeastern Hill Section with an attempt to force larger milk yields by the use of more concentrated feeds in proportion to hay. However, the considerable use of marsh hay as a substitute for tame hay is probably an even more important factor in the situation. Swamp meadow is fairly extensive in the Pitted Sand Plain Section (Figure 5), and in the adjacent areas just to the south, and the farmers find this swamp hay a cheap substitute for the cultivated crop.

In the Pitted Sand Plain Section about 13 per cent of the total hay acreage is in alfalfa in contrast with 2 per cent in the Northeastern Hill Section. Most of the alfalfa is grown in the southwestern half of the Pitted Sand Plain, the percentage showing a rough gradation from much less than 13 per cent in the country just south of Brule to considerably more than 13 per cent in the extreme southwestern end of the section. Two factors appear in the explanation of this increase in the amount of alfalfa grown. Near the southwestern end of the section marl deposits have been opened on the shores of Wood Lake and near several other lakes just south of the Barrens. This material is available for purchase at a low price compared with lime in any other form, and the southwestern part of the Pitted Sand Plain is within wagon haul distance of these

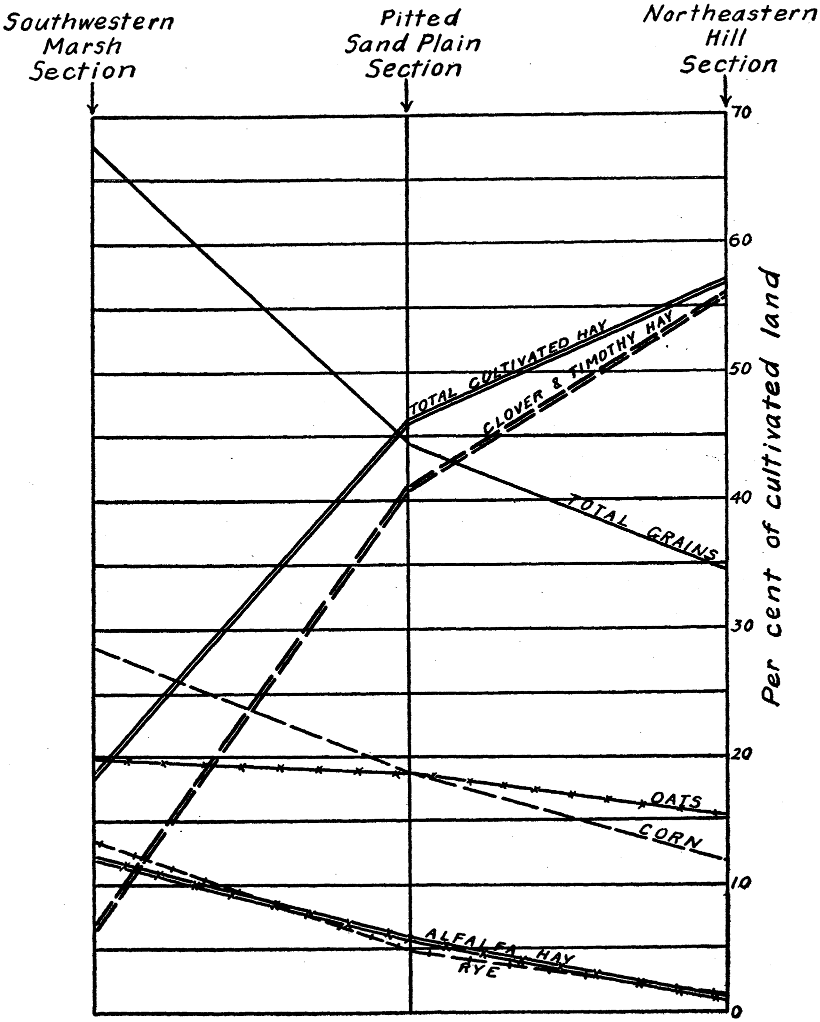

FIGURE 9. Progressive changes in relative importance of various crops and crop combinations from northeast to southeast in the Barrens. (Based on data from Figure 5.)

deposits. The second factor in the situation is an active alfalfa campaign formerly carried out in Burnett County by a man who was then County Agent. At present Burnett County has no Agent, but alfalfa growing goes on, not only inside the County, but in adjacent areas as well. Naturally the crop does better on the loams south of the Barrens than it does in the sand country itself, but it can be grown in the latter by application of lime. With proper fertilization alfalfa has an advantage over other crops, since its long roots equip it to withstand the droughty conditions sometimes prevalent in the sand country in summer.

The higher percentage of the land which is devoted to oats and corn in this area as compared with the Northeastern Hill Section is explainable partly in terms of a lessening relative importance of tame hay for reasons already outlined. The increase in the percentage of cropped land in oats is small, but corn shows an increase of from 12 per cent in the Northeastern Hill Section to 19 per cent here. This would seem to reflect a slight increase in the dependability of the corn crop, but a comparison of frost data for Iron River and Solon Springs shows the latter to have a shorter growing season, a situation which may possibly be due to lake influence at Iron River (Figure 6). At any rate the available climatic data do not explain the higher percentage of land in corn. Location nearer to regions far enough south to have a fairly successful corn crop at least for ensilage may go farther toward explaining the condition.

Potatoes occupy almost exactly the same per cent of the cropped land as they did in the Northeastern Hill Section. Rye and buckwheat have increased in importance, while spring wheat and barley show a decline.

As in the Northeastern Hill Section, small-scale dairying with cream as the exportable surplus is the dominant type of agriculture, and with a few exceptions farm layout and farm practices are quite similar to those in the former section. As might be expected with the increase in corn acreage, silos are more common, averaging one for three and one-half farms in contrast to one for five and one-half farms in the Northeastern Hill Section. The agriculture, too, seems slightly more prosperous, though tar paper covered shacks and log cabins are still the characteristic farm buildings.

The farms of the Pitted Sand Plain are not evenly distributed nor do they show a uniform degree of prosperity. In the northern part of Township 43 N., Range 10 W. and adjacent areas in Township 44 N., Range 10 W. (Figures 1 and 4) there is a cluster of farms known as the Russian Settlement because of the nationality of the settlers, an uncommon group in the Barrens. The prosperous appearance of these farms may be due in part to the great industry of their owners, but the manner in which the soil stands vertically in road cuts in this vicinity suggests that it has an uncommonly high silt content for Barrens soils, despite the fact that the area is all mapped as Plainfield Sand. Other areas of some concentration of agricultural population are (1) a westward extension of the Russian Settlement into the northeast corner of Township 43 N., Range 11 W. and the southeast corner of Township 44 N., Range 11 W., (2) an area of approximately one township just southwest of Solon Springs, and (3) the southern edge of the southwestern part of the Pitted Sand Plain including the outlying "island" and the eastward projecting point just to the west of the island. Contrasted with this are considerable areas in Township 46 N., Range 10 W., and, farther south, Township 42 N., Range 13 W., and Township 42 N., Range 14 W., where less than 1 per cent of the land is under cultivation.

It is difficult to explain adequately such variations in the density of the agricultural population within the sand country. Of course it is nowhere densely peopled, but why should some areas be better settled and more prosperous looking than others? As has been suggested in connection with the Russian Settlement, although all of this soil has been mapped as sand (Figure 3) the soils of some areas appear to have a higher silt content than is normal to the Barrens. Humus content, also, undoubtedly varies considerably over the Pitted Sand Plains, the surface soil being almost pure quartz sand in some localities, and in others dark with humus. Repeated fires seem to destroy what organic matter there is in the surface soil and it is the repeatedly burned over areas which have almost a pure sand soil. Location with respect to villages and main transportation routes, though operating against the occupation of some remote portions of the Barrens, does not appear to have played a very important part in the distribution of the agricultural population as many extensive areas of barrens along the main north-south highway would indicate. Adjacency to better soil areas outside of the Barrens appears locally, as along the southern edge of the southwestern part of the section, to have been important. Chance, too, has doubtless played an important part in the location of the farming population where we find it today.

Everywhere the surplus product of the farm is cream, which is hauled to Gordon, Solon Springs, Danbury, or other railroad points for shipment to the large creameries at Duluth, Superior, and St. Paul. It is significant that only one creamery is situated within the Northwestern Pine Barrens, and that one, located at Grantsburg in the Southwestern Marsh Section, is at the margin of the Barrens and depends almost entirely upon neighboring areas with better soils and more prosperous agriculture. The amount of cream produced is not large enough to justify creameries within the sand country, although, in the southwestern part of the Pitted Sand Plain, trucks from creameries at Spooner and elsewhere in the better farming country penetrate the Barrens. Locally there is a considerable summer sale of milk and cream to the resorts.

Abandoned farms are a characteristic sight in the Pitted Sand Plain, all stages of abandonment being represented. One little shack out in grassy barrens is occupied by an old man who formerly grew corn and a few other crops. Unfortunately, this is one of the areas where fire has left little humus in the soil, and the farmer made no attempt to increase the humus content or otherwise to fertilize the land. After a year or two of use the corn field "got away" and now is a bare expanse of ripple-marked sand. Near the shack a few vegetables are still grown, but they hardly repay the effort, and the old, paralytic settler barely manages to exist. Such subsistence agriculture characterizes not a few of the Barrens farms, and might almost be regarded as the first stage of abandonment. In a second stage of abandonment the people have left the house, some of its windows are broken, and the cleared land of the farm is all in quack grass (Pl. I, fig. 3). Later the house tumbles down and decays, or is burned, and scrub oak, or even jack pine, migrates over the farm until eventually, probably 30 or 40 years after its occupant departed, it has entirely reverted.

Lakes and their Shores

Lake country is by no means continuous in the Pitted Sand Plain, for lakes frequently occur in clusters, while in between and for miles around these groups the country is flat with only occasional dry pits and isolated lakes (Figure 8). Many of these water bodies seem to occupy depressions sunk slightly below the general surrounding level, but in the country south and southeast of Web Lake, an area of many lakes, a general level is hard to detect.

The typical Barrens lake has clear, sparkling water in contrast to the "pea soup" waters of its neighbors on heavier soils, while the sandy soil of the Barrens is free from stones and gives excellent bathing beaches. Moreover, the abundance of roads and the ease with which others are opened and maintained renders the many lakes accessible with a minimum of effort. Bass, pike, pickerel, and muskellunge inhabit those lakes which have not been fished out by the summer visitors who yearly take heavy toll.

The larger lakes and many of the better smaller ones have summer cottages along their shores, and the summer hotel, too, has become very important in the lake country. In addition to the advantages of the typical lake as outlined above there is the factor of relatively low land values which has favored resort use of the Barrens lake shores. Prices are considerably lower than would be the case in a better agricultural section where agriculture would compete with resorts for the land, and, moreover, summer visitors find relatively wild unsettled areas more attractive.

Sometimes accommodations consist of little more than a few one-room furnished cottages with boats for rent and fish bait for sale. This type of resort is particularly common on the smaller lakes, so common in fact, that in spite of every effort to attract trade most of these resorts scarcely make a living. On some of the larger and better lakes more elaborate resorts have been established with a large group of attractively furnished cottages, golf courses, and other accommodations for their wealthy frequenters.

The influence of the resort industry is reflected in the high land values along the shores of many lakes, and is particularly to be seen in the value of improvements since the investment in summer homes and resorts is commonly vastly more than that of the small scale farmer who might occupy the land for agricultural purposes.

From one end of the Pitted Sand Plain Section to the other lake country varies little in appearance and use. The Eau

Claire Lakes 12 miles east of Gordon (Figure 8), Lake St. Croix at Solon Springs, Bardon Lake and its associates southwest of Gordon, Nancy Lake farther southwest, Big McKenzie, Birch Island and Web Lakes to the south — all are alike in their clear waters, their sandy beaches, their summer homes, and their resorts. The hum of summer activity at Gordon, Solon Springs, Minong, and Danbury, and the large and successful grocery stores at these places are further reflections of the summer resort industry.

Not all of the lakes of the Pitted Sand Plain are of value for resorts. It is not unusual to find some swamp land (frequently muskeg with some tamarack trees) bordering even resort lakes at certain spots, while other lakes are almost completely surrounded by swamp, and hence are of little value for the summer visitor trade. The filling-in process responsible for these bordering swamps has gone further in some instances leaving only muskeg and swamp meadow to mark the former lake.

In many of the marshy tracts of the Northwestern Pine Barrens cranberries grow wild. In view of this natural adaptation it is not surprising to find that improved varieties are being grown on a commercial scale. There are at present three such enterprises in the area (Figure 8), each with about 25 acres in producing marsh and an average annual production of approximately 1000 barrels.

The cranberry growing industry of the Barrens is carried on in very close relationship to the natural environment. Fairly cool summers, a normal requisite of the cranberry crop, are enjoyed here just as they are all through central and northern Wisconsin. The necessary acid peat soils are available in the muskeg swamps of the area, and sand is easily obtained at the edge of the marshes, since it is the normal soil of the Barrens. This is a distinct advantage, for application of sand to the marshes every two or three winters causes new runners to take root, checks the growth of weeds, and is beneficial in various other respects.

The more northerly situation of the marshes of the Northwestern Pine Barrens as compared with those of Central Wisconsin means a greater frost hazard. An all-winter flood to protect the vines, and an occasional summer flood because of frost danger or to kill fruit worms are necessary in both areas, but the greater danger of summer frosts in the Northwestern Pine Barrens means more summer flooding. This requires not only facilities for rapid flooding, but facilities for rapid drainage as well, since the vines and berries do no actual growing while under water and are damaged by too long a submergence. A well regulated water supply is, therefore, peculiarly necessary here, and this necessity is reflected in the character of the site chosen. Typically, it consists of a strip of muskeg swamp lying between two lakes the elevations of which are sufficiently different to allow a water supply to be drawn by gravity from the upper one, and, at the same time, to allow gravity drainage to the lower lake. Or, the site may be a similar strip of muskeg lying below a lake and along the stream which naturally drains the lake. In this case the lake forms a natural reservoir of water for flooding purposes and the normal gradient of the outlet stream, after straightening, is sufficient to insure good drainage.

A producing marsh of the Northwestern Pine Barrens presents a striking picture, particularly during the summer season (Pl. II, fig. 4). A long flat swamp tract, bordered on either side by higher, jack pine covered sand country, is divided by dikes about 3 feet in height into plots a few acres in size, the long directions of these enclosures being normal to the general slope of the swamp. Each cranberry plot is carpeted with a green mat of vines, and venturesome vines, together with grass and weeds, spread over the dikes, making them appear as low ridges of green. Irrigation and drainage ditches crisscross the diked fields. On the higher land at the edge of the swamp is the home of the manager, and near at hand are located the grading and storage sheds. An opening in the sand near one edge of the marsh is also a significant item in the picture since it is the source of material for the winter sanding.

Indians from Danbury, Gordon, and other villages gather the wild rice which grows in the swampy parts of many of the lakes in the Barrens as well as elsewhere in Northern Wisconsin. The rice is ripe about the first of September, and the harvest lasts for about a month after that date. The work is all done by hand. Most of the crop thus harvested is sold to the local storekeepers who, in turn, ship it to Chicago and to nearby cities. The grain is in demand (1) as a dressing for wild fowl at sportsmen's dinners, (2) as a cooked breakfast food, and (3) for planting around lakes to which hunters wish to attract wild fowl.

Lakes and their shores are the scenes of several other special activities. There is some fur farming carried on in the same way and presenting the same adjustments as the fur farming in the Northeastern Hill Section. Hay is cut in or around the edges of some of the marshes, but it is not a good type of hay, and is significant here simply because it represents a use being made of the swamp or filled-lake areas.

The Villages

Only three villages lie within the Pitted Sand Plain Section, the largest of these, Solon Springs, having a population of only 778. Gordon, slightly smaller, is a more typical Barrens village (Pl. II, fig. 5) although really located in the St. Croix valley at the point where the Eau Claire River joins the major stream. At a crossroads on the north-south surfaced highway which divides the Pitted Sand Plain almost in half, Gordon is well situated to serve the surrounding country. At this point, too, the Minneapolis, St. Paul, and Sault Ste. Marie Railroad from the southeast crosses the Chicago, St. Paul, Minneapolis, and Omaha from the south. Beyond Gordon they follow essentially parallel courses to Superior. Besides the two railroad stations, the village has two grocery and general merchandise stores, a lumber yard, two filling stations, one combined with a garage, three combined ice cream parlors and restaurants, a town hall, a high school, and a few minor business houses. The rest of the buildings of the village are residential. Both residences and business houses are small and unpretentious, many of them looking quite weather beaten and old. Rising above the village to the northeast is a hill or knob into which the Eau Claire has cut, exposing a surface of fresh sand. Crowning this hill and looming up prominently from any point in the village is a fire lookout tower.

Resort people from Eau Claire Lakes to the east and Bardon Lake to the southwest flock into Gordon daily during the summer season to get the mail and to shop, and this trade is the main support of the grocery stores, and is of importance to all the other business houses of the town as well. The few farmers who live in the country tributary to Gordon bring their cream in to the railroad stations for shipment to Superior or Duluth, and they add somewhat to the local trade. Pulpwood is hauled in by truck and stacked along the railroads, and these long piles of bolts are significant features of the village landscape. Moreover, labor for cutting jack pine is recruited in the village. The garage and filling stations depend partly on business from the people at local resorts and the farmers, but the way in which they fringe the through north-south highway suggests that much of their business is from transients on this road. There are no village industries, the function of the village being en-

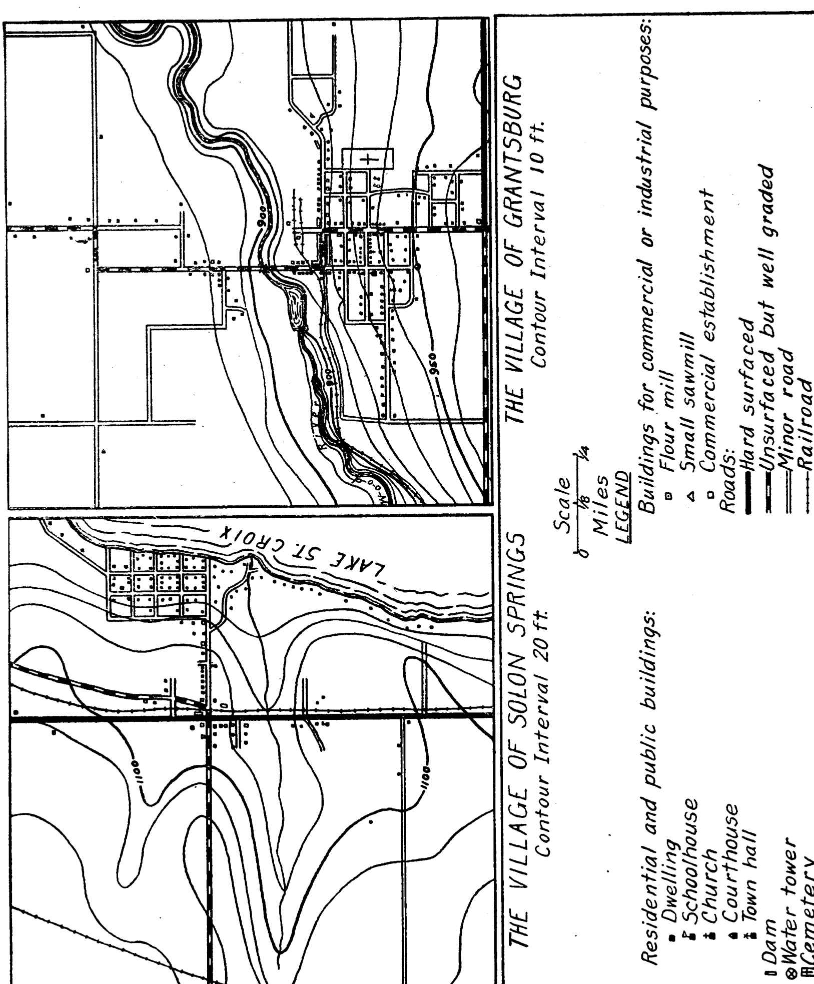

FIGURE 10. Two villages of the Barrens. (After field notes of Wisconsin Geological Survey.)

tirely that of retailing merchandise and of service to the surrounding country and to motorists on the main highway.

Solon Springs on Lake St. Croix is much like Gordon except that it combines the furnishing of merchandise and service with the resort function. Gordon serves resorts some distance away; in Solon Springs the resort and its source of supply are one, though it too serves travelers on the main north-south highway. This combination of the two functions is to be seen in the golf course at the edge of the village, the dance hall and the two hotels in the village proper, as well as in the summer homes and resorts which though located mainly on the lake front grade into the residential and business section (Figure 10).

At the west end of the Pitted Sand Plain Danbury and Webster, though outside the Barrens, perform much the same functions for the sand strip as does Gordon, while south of Gordon, Wascott within the Barrens and Minong outside are of this same character.

THE SOUTHWESTERN MARSH SECTION

Toward the southwest the Pitted Sand Plain grades into a country where pits are few and lakes almost entirely absent. Grassy marshes become numerous, and it is because of their presence that the area is given the name of the Southwestern Marsh Section (Figure 2). Like the Pitted Sand Plain this section has a gentle southwesterly slope, but its surface is smoother than that of the Pitted Sand Plain. There, numerous pits, some lake filled, introduced locally considerable ruggedness; here, large tracts are smooth except for a few low dunes now grass-anchored, and for the almost imperceptible depressions occupied by the marshes. Whole townships show a relief of only 20 to 30 feet. Surrounding the grassy marsh areas and rising as low islands above their surfaces are drier lands covered dominantly by a mixed jack pine and hardwood forest, but with considerable areas of barrens as well. It is on these drier, better drained lands that the scattered farms of the district are located, while abandoned farms, almost as numerous as the occupied ones, are similarly situated.

The table-like surface of the Southwestern Marsh Section is grooved by the narrow valleys of the Clam, Wood, and Trade rivers, while at the west it drops off abruptly along the St. Croix

River (Figure 8). Locally, as west of the mouth of Clam River, swampy terraces mark the transition from the upland to the St. Croix — terraces which are clothed with large hardwoods, and stand out in marked contrast to the typical Barrens above. More commonly there is an abrupt drop from the general upland level to the river.

The extreme flatness of the upland level of the section may be explained as an aggradational effect in the deepest parts of the Barrens Lake, the former presence of which has been postulated.[22] Swamp tracts would be normal features on an old lake plain of this sort, while the dunes that are scattered over the area are considered to be the result of wind work on the bare tracts exposed by the fall of the waters of the lake.

The Southwestern Marsh Section presents two major landscape types: (1) dry lands, which make up 80 per cent of the total area, and (2) grassy marshes, which comprise 20 per cent (Figure 5).

The Dry Lands

About 80 per cent of the Southwestern Marsh Section is dry or well drained land where the typical Barrens alternation of forest and sweet fern barrens occurs, with scattered farms, some occupied and others abandoned.

Approximately 53 per cent of the dry land may be classed as forest or timber land. The timbered areas show no marked concentration, but rather a fairly even distribution with a few forties that may be classed as timbered in almost every section. Jack pine predominates among the species represented, but for the most part it occurs mixed with scrub oak rather than in pure stands. Seventy-five per cent of all the forest of the upland shows this predominance of jack pine, while the other 25 per cent is almost entirely popple and hardwood, the latter including fairly large oaks.

Forested tracts are, of course, included in the pastures of some of the farms, but the dominant type of forest utilization is the same as that of the Pitted Sand Plain Section, the cutting of jack pine for paper making. This cutting is carried on here and there throughout the section in much the same manner that

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[22] Hansell, J. M., The Glacial Geology of an Area in the Northwest Corner of Wisconsin, Unpublished Ph. D. Thesis, University of Wisconsin, 1930.

it is in the Pitted Sand Plain, and piles of bolts are to be seen at Grantsburg and at sidings along the branch line of the Northern Pacific which extends to Grantsburg from the southwest.

About 40 per cent of the dry land is uncultivated and untimbered. A little over 80 per cent of this type is sweet fern and scrub oak barrens, presenting much the same picture as similar country in the more northeasterly sections of the sand strip, while abandoned farms, similar to those described for other sections, make up most of the remaining uncultivated and untimbered land.

Approximately 6.5 per cent of the upland is cultivated. The farms of which these cultivated tracts are a part average 136 acres in size in this section or slightly smaller than those of the Pitted Sand Plain. Eighteen per cent of the average farm is cultivated, the remainder being forest and barrens.

Cultivated land is by no means evenly distributed over the dry land. The most striking departure from such an even distribution is to be seen in the marked concentration of farms along the eastern border of the section, a condition which is particularly noticeable in Township 36 N., Range 19 W. and Township 37 N., Range 19 W., south of Grantsburg (Figures 1 and 4). A possible explanation of this situation is that the silt content of the soil along this edge of the sand country is somewhat higher than that of the average Barrens soil. The influence of neighboring areas of better soils and prosperous farms is a more probable explanation of the condition.

In the Scandinavian ancestry of its owner, the character and appearance of its buildings, and the absence of improved pasture land, the average farm of the Southwestern Marsh Section is much like that described elsewhere as characteristic of the Barrens. Dominance of small scale dairying, with cream as its end product, characterizes the agriculture of this section just as it did that of the more northeasterly sections of the Barrens. The greatest changes are to be seen in the use of the cultivated land. In comparing the Pitted Sand Plain with the Northeastern Hill Section it was found that corn, oats, alfalfa, and rye had increased in relative importance, while clover and timothy hay had decreased. The tendencies suggested by this comparison of the two more northeasterly sections of the Barrens are borne out by a consideration of conditions in the Southwestern Marsh Section. Total hay acreage has continued to decrease in importance relative to total grain acreage (Figure 9). As suggested previously, a two-fold explanation seems to hold for this condition. In the first place, considerable marsh hay is available, and ability to get such cheap hay has meant less emphasis on hay as a crop. Secondly, dairying seems to be progressively more intensive as one proceeds from northeast to southwest across the Barrens. The farmer of the Southwestern Marsh Section attempts to increase his returns by the use of more ensilage and other concentrated feeds in proportion to the hay fed. Computations indicate that there is one silo for each three farms in the Southwestern Marsh Section as compared with one for each three and one-half farms in the Pitted Sand Plain and one for each five and one-half farms in the Northeastern Hill Section.

Alfalfa has likewise increased in relative importance, and, although it occupies only 12 per cent of the total cropped land in the Southwestern Marsh Section, it is more important than clover and timothy hay (Figure 9). This increasing importance of alfalfa toward the southwest throughout the Barrens has already been explained in connection with the Pitted Sand Plain Section in terms of an active county agent and nearness to a supply of marl.

That corn should be of greater relative importance than it was at points farther northeast in the Barrens is probably partly due to a slightly longer growing season[23] in this section, and partly to greater proximity to successful dairy regions farther south where corn for ensilage is a dependable crop.

The increase in the relative importance of oats and rye is a further manifestation of the tendency for the grains to increase in importance in this direction because of the greater use of concentrated feeds. Potatoes, too, show an increase in relative importance, but this increase is too small to be of much significance.

The Grassy Marshes

Although swamp meadows occur in the Northeastern Hill Section and are fairly common in the Pitted Sand Plain, they

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[23] Climatic data available (Figure 6) are by no means conclusive, since records are to be had for only three stations and these stations vary considerably in site characteristics.

are scattered and small, and likely to form a strip along some water course. It is only in the Southwestern Marsh Section that they form large contiguous plots (See areas of peat in Figure 3). There is an irregularly shaped tract of this sort, about a township in size, lying just to the northeast of Grantsburg, while a similar, though smaller, area lies to the southwest of Grantsburg. Here and there throughout these marshes are dry-land islands and small scattered outlying spots of marsh fringe the two main areas.

The landscape presented by one of these swamp meadows is that of an extensive smooth tract of yellowish green surrounded by slightly higher land with its typical Barrens vegetation (Pl. II, fig. 6). Low islands similarly clad dot the grassy sea at rare intervals, while on windy days billows course across its surface. Open water is rare, the swamp character being manifested principally in the sogginess of the sod and in the character of the sedges and grasses, but the amount of soil water and standing water is considerably greater during rainy seasons than during dry.

Among the plants characteristic of these swamp meadows the sedge, "wire grass" (Carex stricta), is of particular interest since it has formed the basis of a special industry, the making of wire grass rugs. The Crex Carpet Company of New York and St. Paul began operations here in 1911, purchasing 23,000 acres of marsh land from which to cut wire grass for their St. Paul factory (Figure 8). A large amount of wire grass was cut during the first year or two of operations in the Southwestern Marsh Section, the total reaching 7000 tons in one year. At present the company averages much less than this, partly as a result of the decline in the grass rug business and partly because production conditions are more favorable in the several scattered areas in Minnesota from which a considerable part of their raw material is still obtained.

At present three camps are operated in the marshes of the Barrens during the cutting season. Cutting begins about July 6th and from then until the end of the season, early in September, there is considerable activity in the meadows. The wire grass is all ready for cutting by July 1st, but it can stand for a long time without spoiling, so the harvest season can be spread over several months. Tractors are in use everywhere to pull the machinery used in cutting and bundling the "grass," and to pull the loads of bundles to the baler. The broad tread of tractors makes it possible to use them to better advantage than horses on the soggy ground of the marshes.

Field operations are closely related to moisture conditions. Rains interfere with the cutting and even more with the drying, so in rainy weather the workmen are idle or go back to their nearby farms. A year with considerable rain in the early summer is desired since it gives wire grass that is longer and of larger diameter than that of a drier year, and the yield is greater if the rain stops in time to allow cutting operations to go on. Thus the summer of 1928 was wet and there was a particularly good stand of wire grass, but so much water stood in the marshes that harvesting was difficult and only about 150 tons were shipped. The summer of 1929 was dry, the "grass" was shorter and smaller in diameter, but it could be got at for harvesting and the yield was about 1000 tons, almost seven times that of the wet year. In very dry years there is a constant fire hazard. Dry years are undesirable, too, because under such conditions other species grow better than the wire grass and crowd it out. The desirable condition seems to be a water table kept just beneath the surface, thus giving enough water for the "grass" but not enough to interfere with the harvesting operations.

The first field operation is the cutting. At the beginning of the field season the drying which follows takes three days, but later the "grass" still standing has dried somewhat and one day after cutting is considered sufficient in dry weather. After drying, the "grass" is bundled or shocked and hauled to the baler which is located on one of the few roads which penetrate the marshy areas, roads which follow peninsulas and islands of drier land as far as possible. The bales are hauled by truck to Grantsburg and shipped thence to the St. Paul factory.

Under the present methods of operation all the wire grass cut is baled as soon as it is hauled from the fields. The stacks to be seen here and there near the edges of the swamp meadows belong to local farmers to whom the Crex Carpet Company has rented the privilege of cutting the marsh hay in areas where the proportion of wire grass is too low for the Company to operate at a profit.

Trade Relations of the Southwestern Marsh Section

The dry lands of the Southwestern Marsh Section are well served with roads, thus contrasting with the poorly served marshes of the area (Figure 7). As elsewhere in the Barrens, the road pattern is rectangular, with roads on every section line in some localities. Most of them are merely two ruts, but the country is flat and there are no difficult hills to climb. Moreover, a road once cleared remains passable for many years. These secondary roads are tributary to graded roads which focus upon Grantsburg, the principal trading and cream buying center for the section.

Grantsburg, with a population of 800, is located on Wood River at the southeastern margin of the Barrens. The southern edge of the sand country divides the village almost in half, the north part lying on the flat Barrens, the southern part on the fairly steep north face of the heavier soil area which rises to the south (Figure 10).

The village of Grantsburg was founded in 1869 by Canute Anderson, who built the first store, a saw mill, and a grist mill.[24] Other settlers soon followed. It is significant that the four people considered important enough to mention in the discussion of Grantsburg in a history of Northern Wisconsin, published in 1881, are the founder, Canute Anderson, and three other Scandinavians, Magnus Nelson, Ole Berg, and Thor Ingebrigtsen. For the first twenty years of its existence the village was without a railroad. Its somewhat out-of-the-way location kept any of the main lines from passing through, and it was only by private enterprise that a branch line to Rush City, Minnesota (Figure 1), was finally established. This has since been taken over by the Northern Pacific Railroad with which it connects. From time to time in the history of the village, small saw mills have manufactured lumber for local use, but Grantsburg was never a lumbering town.

Grantsburg is today a normal farming village with Norwegians the dominant population type. Its people are, for the most part, retired farmers together with the tradespeople who serve them and the neighboring farming population. The function of county seat adds somewhat to the importance of the vil-

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[24] History of Northern Wisconsin, the Western Historical Company, Chicago, Illinois, p. 170, 1881.

lage and is responsible for its most prominent building, the court house. Grantsburg is stodgily built with typical American frame houses designed for service rather than for beauty. However, the houses are set far apart, and lawns, with oak and evergreen shade trees, give the residential part of the village a pleasing appearance. The street pattern is rectangular with the long direction of the residential section extending from east to west, or normal to the direction of slope of the land. The business section, though with a similar trend, is on the flat terrace land along Wood River. As might well be expected, it is to the more prosperous farming areas to the southeast that the stores and the creamery of the village look for most of their business, and not to the Barrens. Although it serves to some extent the lake country several miles southeast of it, Grantsburg is dominantly a farmer's town as its several large hardware and implement stores would suggest. A flour and feed mill, a descendant of Canute Anderson's grist mill, located in the Barrens part of the village and obtaining its power from a dam on Wood River, depends almost entirely upon spring wheat grown on the heavier soils to the southeast. Very little of the wheat ground is from the Barrens, the small relative importance of this crop in the sand suggesting that it does not do well enough to be grown for sale in competition with wheat from the loam areas. There has been a tendency within recent years for the village to extend itself in a north-south direction along the highway, filling stations being particularly prominent in these extensions.

Although the Barrens is not of great importance to Grantsburg, the village is of considerable importance to the sand country. It is here that much of the cream is shipped, while piles of boltwood along the railroad and cars being loaded with bales of wire grass indicate that this is the point of departure for products of the Southwestern Marsh Section which are to reach the outside world. Considering Grantsburg's railroad connections, it is not surprising that its trade relations are more with St. Paul and other Minnesota points than with Wisconsin cities, but the automobile is tending to offset these Minnesota ties.

Although Grantsburg is the hub of the Southwestern Marsh Section, not all the products of the region pass out through this village, and not all of its trading is done here. Boltwood is piled at several points along the railroad west of Grantsburg and is shipped out to the main line in that direction. The extreme southern part of the section sends its cream east to the Cushing Creamery just east of the Barrens edge (Figure 1), while some of the people go to Luck, St. Croix Falls, and other points to the south and east to buy supplies.

EXPLANATION OF PLATES

PLATE I

FIG. 1. Typical Vilas Hill Country topography.
FIG. 2. A pit in sweet fern and scrub oak barrens.
FIG. 3. An abandoned farm in the Pitted Sand Plain Section.

PLATE II

FIG. 4. Summer view of a producing cranberry marsh near Big McKenzie Lake.

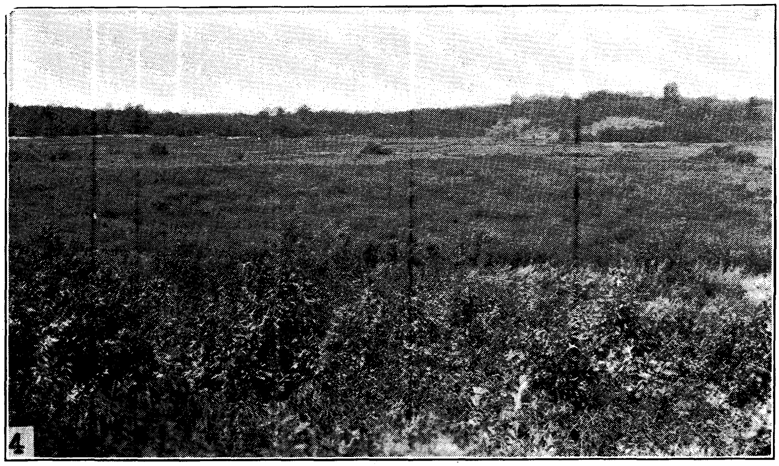
FIG. 5. The village of Gordon as seen upon entering it from the south on the main north-south highway.

FIG. 6. Harvesting operations in progress in the Crex Meadows southwest of Grantsburg.


1


2


3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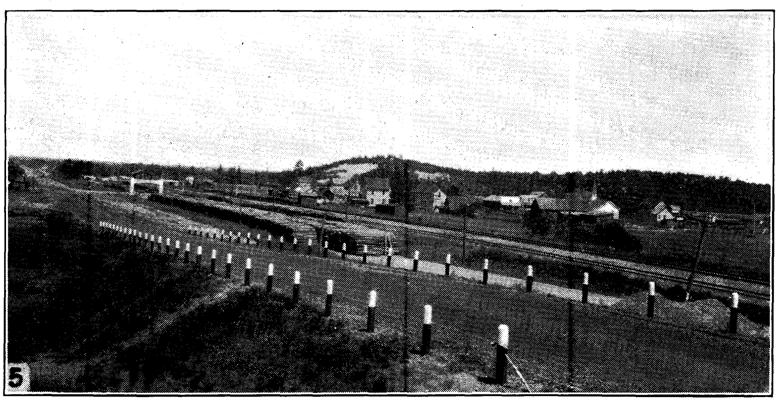
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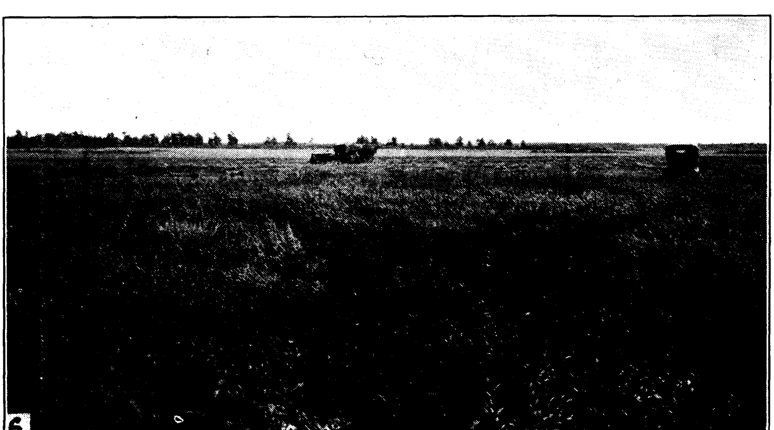
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NOTES ON THE LATE ORDOVICIAN STRATA OF THE GREEN BAY—LAKE WINNEBAGO REGION

JEANETTE JONES

The Late Ordovician strata are generally known as the Richmond group, representing the uppermost part of the Cincinnatian series. The Ohio Valley includes the type locality of the Richmond, found in Ohio and Indiana. In this region, the Richmond is divided into six formations. Given in ascending order these are: Arnheim, Waynesville, Liberty, Saluda, Whitewater, and Elkhorn.

In the Mississippi Valley States is another area of Richmond rocks, classified independently from the Ohio Valley Richmond. Definite division and correlation have been less extensive in this region, and practically no extensive correlations have been made between this area and the Ohio Valley Richmond. The Maquoketa of Iowa occupies a prominent position in the Mississippi Valley States, for it has been recognized as a distinct lithological unit since its first mention by C. A. White (5) in 1870. The most recent work in this area has been done by H. S. Ladd (3). In his report, the Maquoketa has been divided into four members, known in ascending order as: Elgin, with a basal, depauperate fauna zone, Clermont, Fort Atkinson, and Brainard, with an upper or *Cornulites* zone. Correlation of these members places the *Cornulites* zone as equivalent of the Elkhorn of Ohio, while the Depauperate fauna zone is correlated with the Arnheim.

The Richmond of northeastern Illinois has been studied by J. C. Evans, (1) whose results are embodied in a Ph.D. dissertation at Chicago University. Though comparison of the fauna of the locality with the Ohio Valley fauna is given, no definite correlation was made. The formation in general is divided into three horizons, the lower shale, middle dolomite, and upper shale members.

R. C. Hussey (2) has studied recently the Richmond of Michigan, which outcrops on the Bay de Noc peninsula. The formation is divided into three principal divisions, known in ascending order as the Bill's Creek beds, Stonington, and Big Hill members. Correlation of these members with the Ohio Valley Richmond places the Big Hill as the equivalent of the Whitewater-Elkhorn, and makes the Stonington equivalent to the Whitewater-Elkhorn down through the Waynesville. The Bill's Creek beds are considered equivalent to the basal Maquoketa of Iowa.

A general table showing the type Richmond and the several correlations which have been made is as follows:

	Ohio Valley	*Iowa*	*Michigan*
Richmond	Elkhorn	Brainard (Cornulites)	Big Hill
	Whitewater		Stonington
	Saluda		
	Liberty		
	Waynesville		
	Arnheim	Elgin (Depauperate)	Bill's Creek
Maysville			
Eden			

No correlation of the above strata has been made with the Wisconsin Richmond, which outcrops in a narrow north-south belt in the eastern part of the state. The work to be reported in this article is the correlation of this formation with similar strata in Iowa, Illinois and Michigan, and, so far as possible, with the Ohio Valley Richmond.

Lithology

The lithological characteristics of the formation in the Green Bay—Lake Winnebago area present extreme variability. Exposures were inspected in thirteen localities, covering an area of at least one hundred and fifty miles in length, and detailed sections were made at Bay Settlement, on Green Bay, and High Cliff and Shannon's Harbor, the two latter localities on the east shore of Lake Winnebago. Local variations in the several lithological units were very pronounced. Attempts were made to compare the several sections with well records from Sturgeon Bay, Chilton, Brillion, West Bend, New Holstein, and Hartford. The Richmond in these shows an average thickness of 375 feet, and consists of an alternating series of shale and dolomite strata. A generalized section by F. T. Thwaites, (4) in his report on Paleozoic rocks in deep wells in Wisconsin, gives an excellent summary of the characteristics of the Richmond as determined by these deep well borings.

Summarizing the characteristics, the exposures seem to include two areas possessing different aspects lithologically, namely, the Green Bay area and the Lake Winnebago area. The Green Bay area shows, in descending order:

1. A disconformable contact with the overlying Silurian, as suggested by the presence of phosphatic nodules along the bedding planes of the latter, and also occasional ripple marks along the bedding planes.
2. Approximately 20 feet of non-calcareous, unfossiliferous shale, with scattered, thin bands of dolomite, at the top of the Ordovician.
3. A thickness of 50 feet of disintegrated shale, highly fossiliferous.
4. A marked coral zone, with a stratum rich in *Streptelasma,* underlain by a stratum filled with *Columnaria alveolata.*
5. Approximately 50 feet of alternate, thin, shale and dolomite strata.

Characteristics of the Lake Winnebago area are:

1. At the top, a cherty, blue to buff, dense dolomite immediately overlying the shale, with a clean, sharp contact between.
2. A thickness of 15 feet of green shale, highly fossiliferous.
3. Approximately 50 feet of dark green shale, unfossiliferous, with occasional, thin, brown dolomite strata, with numerous Bryozoa.

The essential differences between the two areas lie in the contact with the overlying Silurian dolomite, and the extensive, unfossiliferous beds of shale in the lower part of the section in the Lake Winnebago area.

FAUNAL DEVELOPMENT

The faunal study in the region has shown a variability similar to that of the lithology. The representation of the various phyla is very limited, appearing more restricted than in the Iowa Maquoketa area. Only five phyla are represented in the faunal collection made at Bay Settlement, namely:

Phylum	*Class*	*No. species*
Coelenterata	Anthozoa	5
Vermes	Chaetopoda	1

Echinodermata	Asterozoa	1
Molluscoidea	Bryozoa	9
	Brachiopoda	30
Mollusca	Gastropoda	2
	Pelecypoda	2

The absence of trilobites and graptolites, and the rare occurrence of pelecypods is notable.

Several of the species show considerable variation, many, outwardly similar to the Ohio Valley Richmond forms, differing by features distinct enough to give varietal rank to the species. Six new forms were observed. These will be named and described in a later publication. They will be referred to here as follows: *Rhynchotrema anticostiensis var., R. neenah var., Hebertella sinuata var., Wilsonia (?) sp., Lioclemella sp., Streptelasma sp.*

The general appearance of the fauna, however, shows a characteristic upper Richmond facies, especially such forms as *Rhynchotrema capax* and *Platystrophia acutilirata.*

Fifty species have been described from the region:

Columnaria alveolata
C. stokesi
Protarea richmondensis
Streptelasma rusticum
Streptelasma sp.
Cornulites sterlingensis
Promopalaester wisconsinensis
Batostoma sp.
Bythopora delicatula
Ceramoporella ohioensis
Corynotrypa inflata
Dicranopora fragilis
Hallopora subnodosa
Lioclemella annulifera
Lioclemella sp.
Monticulipora epidermata
Dalmanella carinta
D. meeki
Dinorthis subquadrata
Hebertella alveata
H. alveata richmondensis
H. occidentalis
H. sinuata var.
Leptaena unicostata
Plectorthis sp.
Platystrophia acutilirata
P. clarksvillensis
P. cypha
P. foerstei
P. laticosta
P. attenuata
P. cumingsi
Plectambonites sericeus
Rafinesquina alternata
R. alternata noquettensis
R. inflata
R. kingi
Rhynchotrema capax
R. anticostiensis
R. anticostiensis var.
R. perlamellosum
R. neenah var.
Strophomena planumbona
Strophomena sp.
Wilsonia sp.
Zygospira modesta
Cuneamya sp.
Modiolopsis sp.
Conularia sp.
Trochonema sp.

the Elkhorn — Whitewater — Liberty formations of the Ohio Valley Richmond:

Columnaria alveolata
Protarea richmondensis
Streptelasma rusticum
Bythopora delicatula
Corynotrypa inflata
Monticulipora epidermata
Dinorthis subquadrata
Hebertella alveata
H. occidentalis
H. sinuata
Platystrophia acutilirata
Plectambonites sericeus
Rafinesquina alternata
Rhynchotrema capax
R. perlamellosum
Zygospira modesta

Ten species are common to the Green Bay region and the Cornulites zone of the Iowa Maquoketa.

Streptelasma
Cornulites sterlingensis
Bythopora delicatula
Lioclemella annulifera
Dicranopora fragilis
Leptaena unicostata
Rhynchotrema anticostiensis
Rafinesquina kingi
Rhynchotrema neenah
Strophomena planumbona

Nineteen species are common to the region and the Richmond of northeastern Illinois.

Dalmanella carinata
Dalmanella meeki
Dinorthis subquadrata
Leptaena unicostata
Platystrophia acutilirata
P. clarksvillensis
Plectambonites sericeus
Rafinesquina alternata
R. inflata
Rhynchotrema capax
R. perlamellosum
Cornulites sterlingensis
Hallopora subnodsa
Ceramoporella ohioensis
Dicranopora fragilis
Strophomena planumbona
Zygospira modesta
Platystrophia attenuata
Platystrophia cumingsi

Twenty one species are common to the region and the Richmond of northern Michigan.

Columnaria alveolata
C. stokesi
Protarea richmondensis
Streptelasma rusticum
Cornulites
Hallopora subnodosa
Corynotrypa inflata
Monticulipora epidermata
Dinorthis subquadrata
Hebertella alveata
H. alveata richmondensis
H. occidentalis
Platystrophia acutilirata
P. clarksvillensis
P. cypha
Rafinesquina alternata
R. alternata noquettensis
Rhynchotrema capax
R. perlamellosum
Strophomena planumbona
Conularia

CORRELATION

With such a faunal representation in the different areas, several suggestions may be made concerning the stratigraphic equivalents of the Wisconsin Richmond. These are as follows:

1. The strata of the Green Bay—Lake Winnebago region represent equivalents of the Elkhorn — Whitewater — Liberty formations of Ohio.
2. The formation may be correlated with the Upper Brainard or *Cornulites* zone of the Maquoketa of Iowa.
3. The strata may be equivalents of the Stonington and Big Hill formations of the Richmond of northern Michigan.
4. The strata may represent equivalents of the Richmond of northeastern Illinois.

With such correlations, it would be logical to assume that the Richmond of eastern Illinois, Wisconsin, and northern Michigan represent a continuous formation. This was probably deposited by a northern invading sea, with variations produced as the sea advanced toward the south, with many oscillations of the strand line. The presence of numerous corals of a northern variety in Michigan and Wisconsin, and a disappearance of the same in the Illinois area substantiates this conclusion.

Further study is necessary in this region, and the location of definite faunal zones must be established before more specific correlations can be made. The major part of the collections herein recorded was secured from the fragments in the weathered debris from the cliffs. The time available for field work was limited; however, it is believed that this study may serve as an introduction to the extensive problems which remain.

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THE MENOMINEE TREATY AT THE CEDARS, 1836

Louise Phelps Kellogg

So far as known the Menominee Indians have always had their habitat in what is now Wisconsin. When the French discoverers floated down the pellucid waters of Green Bay they found a tribal group at the mouth of the river, ever since called by their name the Menominee, and throughout the three hundred years of Wisconsin history the Menominee Indians have dwelt in this vicinity. Ethnologists believe that they were a branch of the great Algonquian family, which in the centuries of pre-history were slowly pushing westward from the Atlantic coast plains. Possibly the ancestors of the Menominee came southward from the great northern plains stretching out toward the Arctic, but if so all memory of such origin seems lost. The Menominee legends center around the southern shores of Lake Superior and the northwestern shore of Green Bay. Even their name must have come to them while residing in the rice-filled waters of streams in Michigan and Wisconsin, for in the vernacular Menominee means people of the wild rice or as the French translated it *les folles avoines* (foolish oats).

It would be aside from our purpose to trace the history of the Menominee from the time of their discovery to the treaty of 1836. Suffice it to say that as a rule these tribesmen were friendly to the white invaders, that they welcomed their successive rulers — French, British, and American with good will, and that it was their boast — not strictly true, however, — that their tomahawk had never been raised against their white brethren. As faithful allies of the British they took part in the War of 1812 and at its close signed in 1817 a treaty of amity and friendship with the American nation. It was on soil that had belonged to the Menominee that the first American post in Wisconsin was built at Fort Howard and thenceforward they were ready to join in the activities of their new American allies. Their complaisance went so far that they welcomed into their midst a migratory group of Indians from New York state

— Oneida, Brothertowns, and Stockbridges, whom the white people of New York wished to push from their borders. These eastern Indians made much trouble for the Menominee, and it was in connection with these difficulties that treaties were made previous to that of 1836.

At the famous Prairie du Chien gathering of 1825, called by the government to put an end to the intertribal quarrels and to arrange definite boundaries between tribal regions few Menominee were present. The final adjustment of the boundaries between the Menominee and their neighbors, the Chippewa and Winnebago, was left therefore until the treaty of 1827 at Butte des Morts. Then in 1831 several Menominee chiefs were escorted to Washington to see their Great Father, the President and to make him a cession of their lands. It was at this time that the tribal chiefs made a statement of their claims to Wisconsin lands, stretching from Milwaukee River to the Eau Claire, from Escanaba to the Fox-Wisconsin portage.[1] The government never granted the validity of these claims; nevertheless they embodied them in the first article of the treaty of 1831. These boundaries conflicted on the east with those of the Potawatomi, in west and central Wisconsin with the tribal homes of the Sioux and the Winnebago and as such they were bought out by the government in successive treaties. The treaty of 1831 at Washington ceded to the United States all the Menominee tract from Green Bay to the Milwaukee River, east of a line from Fond du Lac to the headwaters of the Milwaukee. The Potawatomi claims to the region west of Lake Michigan were settled at the Chicago treaty in 1833.

For this great cession of eastern Wisconsin the Menominee received a mere pittance. For that portion, which they assigned to the New York Indians they were granted $5,000 a year for four years. For all the rest of this great tract they received $6,000 a year for twelve years, with an immediate purchase of $10,000 worth of provisions, clothing, etc. These may seem considerable sums, but when divided among the nearly 3,000 members of the tribe the amount per person was insignificant. The government attempted to prepare the Menominee for an inde-

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[1] See Section one of Treaty of 1831 in Charles J. Kapler, *Indian Treaties*, (Washington, 1904) 319. In 1929 Peter La Motte, a Menominee chief made a map, showing these claims and presented it to the author of this article.

pendent life by arranging for the tribe a demonstration farm. This farm was established at the place where Lake Winnebago empties into the lower Fox. Five farmers dwelt there and five housewives to teach Indian women domestic economy. (Was not this the first home economics school in Wisconsin?) A mill was built and a miller employed to run both a saw and grist mill. The lumber was to be used to build homes for the Menominee and when they were settled they were to be furnished with horses, cows, hogs, and sheep. Their children were to have a school, taught by competent instructors. All these methods were expected to be so efficacious that "in four years [it is] to be hoped their hunting habits may cease and their attention be turned to pursuits of agriculture."[2]

The optimists of the Treaty of 1831 counted without a deep knowledge of Menominee character. All this welfare work was of very little use to them, and they highly resented having their own money spent on such an establishment. As one of their chiefs said at the treaty of 1836: "We don't want schools, we don't care to have our children learn to read." The whole benevolent plan was regarded as a scheme for a number of white people to make money out of the Indians' funds and to build up an establishment of no use to the tribesmen. Oshkosh, the head chief, had not attended the treaty at Washington; he and his party grumbled loudly at the foolish provisions Grizzly Bear had been entrapped into signing. Meanwhile Grizzly Bear died and there were few to defend the treaty which he was instrumental in signing. The annuities were too small to be of much benefit to the hungry, idle mob of Indians with "hunting habits;" their neighbors, the Winnebago and Chippewa, had larger annuities. They wanted to sell more land and have more ready money.

This was the situation as far as the Menominee were concerned when Wisconsin Territory was organized in July, 1836. The new territorial governor, Henry Dodge, was an old Indian fighter; he had, moreover, a respect and liking for his Indian wards and a desire to do them justice. Upon taking office Dodge was informed that Indian affairs for the entire territory were under his charge; he was also instructed to purchase additional land from such tribes as were willing to sell, and in so far as

[2] Text of the treaty, Kapler, *Indian treaties* 323.

possible to persuade the Indians to cede all their Wisconsin territory and to remove west of the Mississippi River. This was in accord with President Jackson's policy of Indian removals, then in full swing for the tribesmen of the southern states.

In the meanwhile Oshkosh and Silver at the annuity payment of 1835 had told their Indian agent that they were ready to consider selling land north and west of Lake Winnebago; this offer was reported to the Indian commissioner. He was told it was "as fine a body of lands as ever were offered for sale; the purchase will be of inconceivable value to the settlement and prosperity of this territory."[3] Cass, then secretary of war, had sent a special agent all through the Indian country to listen to grievances and to report on conditions. Cass's confidential agent told him that the Menominee were ready to sell[4] and Cass in March, 1836 gave the President to understand that the Indians near Green Bay were disposed to make a cession and suggested their removal beyond the Mississippi. Cass was well-acquainted with the resources of Wisconsin and knew it was only a matter of time when this new territory must be a white possession open for the settlement of the great mass of emigrants pouring in from the East and from Europe. Dodge was therefore ordered to see about the Menominee matter at once.

Aug. 16, 1836 Dodge wrote a friend at Washington that he was leaving his home, not far from Dodgeville, on the following day, expecting to treat with the New York Indians while the Menominee were assembling. "I will be on the ground," he wrote, "to watch the course of events and the currents and counter currents that I may have to contend with."[5] Among these currents and counter currents must be considered the influence of the principal settlers of Green Bay, several of whom were allied by birth or marriage with the Menominee tribe. Aug. 3 Louis Grignon wrote his brother Augustin: "It appears certain that a treaty is about to be held here for which Governor Dodge is or will be the sole commissioner, but as yet all

[3] Gen. George M. Brooke to Commissioner Elbert Herring. Indian Office Files. Oct. 21, 1835.

[4] Report of Edmund Brush to Lewis Cass. Indian Office Files, Dec. 29, 1835.

[5] *Annals of Iowa,* III Series, Vol. iii, 384.

is obscure; we do not know when it will take place. As the season is advanced it is supposed that it will be very soon."[6]

Among the few Americans at Green Bay were Colonel George M. Boyd, Indian agent, who had been transferred from Mackinac four years before and Henry S. Baird, a young lawyer seeking fame and fortune in the new territory. The former attended the treaty in his official capacity; the latter was chosen secretary for the commission. It was doubtless they who suggested the place for the conference at a site on Fox River just below Grand Chute, known as The Cedars. This site is directly opposite the modern town of Kimberly, on section 20, town 21 north, range 18 east. This may have been the place mentioned by Stambaugh in his "Report on the Quality and Condition of Wisconsin Territory, 1831." "The scenery is very fine at this place [Grand Chute] and indeed along the whole course of the river. Some distance below the Chute there is a bold prominance at an angle in the river, which overlooks seventy miles of the rapids, which present an interesting and beautiful spectacle."[7]

The site at the Cedars was chosen not only for its prominence, but also for its convenience. Most of the Menominee lived east and north of it. If the appointed place were above Grand Chute they would be obliged to portage all their canoes and possessions. Any place lower down stream would be too accessible to white settlements and to the whisky-shops among them. Runners sent out to all the villages and camps along the Menominee, Oconto, and Wolf rivers summoned the tribesmen to the council. They began arriving late in August and Governor Dodge came in on the morning of August 26.[8]

One is tempted to let imagination play about the scene — the constant arrival of the canoes with their human freight, chiefs and warriors clothed in their best ceremonial finery, gaudy with barbaric ornament, their scalp locks greased and erected into towering panoplies for eagle feathers, upon their chests necklaces of bear's claws and wampum, mingled with the presidential medals given to those of the chiefs who had visited

[6] Translation of the French original in Wis. Hist. Library. Wis. MSS. 38B2.

[7] *Wis. Hist. Colls.*, xv, 417.

[8] Letter of John Lawe to his daughter Rachel, dated at the Cedars, Aug. 28, 1836. "Governor Dodge arrived here the day before yesterday morning." Wis. MSS. 5C14.

Washington. Excited women, children, and dogs ran hither and thither, wigwams were quickly erected, fires built, kettles hung, and all the incidents of savage life at its heightened moments unrolled before the spectators. Most of the visitors were too familiar with these incidents to be impressed. Prominent traders both French and American gathered from east and west. Among these we note Joseph Rolette from Prairie du Chien; Louis and Augustin Grignon, grandsons of Charles de Langlade; John P. Arndt, the taverner of Green Bay; John Lawe and the younger Porlier, also pioneers of this region; Charles R. Brush, Sam Ryan, newcomers to the territory; Joseph Jourdain the settlement blacksmith. While striding among these white men were army officers from Fort Howard, Brigadier General George M. Brooks and Lieutenant Robert E. Clary.[9] Two young Menominee half-breeds, Charles A. Grignon and William Powell, were sworn in as interpreters, both having Menominee mothers and speaking the language with ease. Other half-breeds were there also to obtain their share of the purchase money, and their influence upon their relatives, the chiefs, was one of the "currents and counter-currents" with which Dodge had to contend. There were also present eight missionaries of various denominations, who with the traders were anxious to see the treaty signed, although from different motives. The former desired to have their charges removed from the neighborhood of the whites, and so encouraged them to sell. The traders hoped to secure payment for debts long due them from their Menominee customers. N. G. Bean wrote to John Lawe, at the beginning of the negotiations: "You are the Father of the Nation [that is, its chief trader], they won't sign without your approval. Your joint efforts should procure something handsome to be equally divided."[10]

Dodge soon found that stubborn opposition would be put up to any scheme of removal to the west of the Mississippi, so he quickly abandoned all such suggestions and set himself to obtain the most land on the best terms that could be secured. He appreciated the value of what the Indians had to sell and the importance of treating them fairly. As he wrote to a friend: "The growth of our Territory is so intimately connected with

[9] Signatories to the treaty in Kapler, *Indian Treaties*, 465-466.
[10] Wis. MSS. 507.

our Indian relations, that I view it as a matter of the first importance to do the Indians ample justice in all our treaty stipulations. A little Indian difficulty would greatly impede the settlement of the country, and experience has given us some useful lessons on this subject as to the expense of Indian wars."[11] In other words a treaty, at almost any price, was *cheaper* than a war.

The council opened Monday morning, Aug. 29 at ten o'clock.[12] Dodge reminded the chiefs of a clause in the treaty of 1831 by which they were to hold the land north and west of Fox River until such time as the President should deem it expedient to extinguish the title when the Indians promised to surrender it immediately. This proviso took the Menominee aback. Oshkosh and his fellow chiefs protested that they had never made such an agreement. Dodge thought it best to waive this proposition and to allow the chiefs to make their own proposals as to bounds and price. Wednesday, Aug. 31, Oshkosh offered all their lands east of Wolf River, which he estimated at three millions of acres. Dodge then asked for something on Wisconsin River to comprise pine timber needed by the new settlers for building. A grant was made of twenty-four miles in length, three miles each side of the river, comprising in all eight townships. Dodge estimated that the whole grant would be "upwards of four million acres." What they asked for this property footed nearly $2,000,000, which Dodge could by no means allow. He scaled down the annuities demanded from $80,000 to $23,500 annually for twenty years, made the traders agree to cut their claims in half, appropriated $80,000 for the half-breeds and promised salt, tobacco and clothing to be furnished at the annual payments, which brought the total sum agreed upon to somewhat more than $700,000. This was one of the largest amounts paid up to this time for an Indian cession. Dodge would gladly have given more, knowing the value of what the Indians sold; but he was certain that larger payments would imperil the ratification of the treaty by the United States Senate.[13] The traders, concluding that "half a loaf was better than no bread," and that there was danger that the nego-

[11] *Annals of Iowa,* III Series, vol. iii, 386.

[12] "Journal of the Proceedings" in Indian Office Files. Negotiations in Henry S. Baird's writing in Wis. MSS. 73C.

[13] *Annals of Iowa,* III Series, vol. iii, 386.

tiations would be broken off, urged the chiefs to sign. So on Sept. 3, only six days after opening the conference the principal chiefs "touched the pen," Dodge, Baird, and Boyd appended their signatures and the treaty of the Cedars was made. The next February the Senate ratified it and the following year the Menominee prepared to abandon their village homes, theirs from time immemorial, on the lower Fox, the Oconto, the Menominee, and to establish new homes west of Wolf River, between there and the Wisconsin.

The treaty of 1836 with the Menominee was remarkable for several reasons. In the first place it was noted for dispatch — the Indians gathered, their ceremonial speeches were made, propositions were discussed and agreed to in less than a week. This was, perhaps, because there was but a single commissioner and he well-versed in his duties, acquainted with the Indians, their traders, their relatives and friends, as well as with the nature of the ceded territory. Secondly, this treaty was noted for its fairness, practically all parties were satisfied with its provisions and its results. Lastly, it was remarkable for its effect on the growth of Wisconsin Territory. Today great cities stand on this Indian cession — most of Oshkosh, all of Neenah, Menasha, Appleton, North Kaukauna, Oconto, and Marinette in Wisconsin, Menominee and Escanaba in Michigan owe their origins to the treaty of the Cedars. On the Wisconsin River, also, Wisconsin Rapids, Stevens Point, Mosinee, and Wausau stand on the strip ceded to the government in 1836.

The carrying out of the provisions of the treaty occupied some time. In 1837 commissioners were appointed to take testimony regarding the traders' claims. From this report many interesting bits of early Wisconsin history may be gleaned.[14] Jacques Porlier testified that he began trading with the Menominee in 1796; Peter Powell had been for twenty-five years one of their traders; Louis Grignon had had twenty-nine years' contact with this tribe; John Lawe had not only traded with them since 1810 but had fed them, clothed them, cared for them in a hundred ways. The commissioner chosen by the President to pay the claims of the mixed-breed Menominee was John W. Edmonds of Indiana. "He will have," wrote Dodge, "a delicate and difficult task." He came to Green Bay in the summer of

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[14] Indian Office Files; photostats in Wis. Hist. Library.

1837 and paid most of the claims at the time of the payment. The sums seem to have amounted to three to four hundred dollars per person. We have an account of the payment of that year from the pen of James M. Boyd, son of the Indian agent, who was present on that occasion.[15] The tribe was to have been paid on Lake Poygan, but the money came so late in the year that the party stopped at Grand Chute and called the Indians there. Like most such payments it had its ludicrous and tragic incidents and one may seriously question whether the annuities were not more harmful than helpful to the Menominee. In one respect they played an important share in the fiscal history of the territory. Money was scarce on the frontier, and the coin brought by the government agents for the Indians created a circulating medium which aided the new commonwealth to tide over the difficult days of the panic of 1837. So far as the white dwellers in Wisconsin were concerned the treaty of 1836 and its effects were of great importance to their progress. For the Menominee the treaty of 1836 still stands as a landmark in their dealings with their "great Father" for justice, fairness, and a recognition of their rights.

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[15] MS. in Wis. Hist. Library. File 577.

SHAFTESBURY AND THE DOCTRINE OF BENEVOLENCE IN THE EIGHTEENTH CENTURY

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The utilitarianism represented by Hobbes on the one hand and by Locke on the other, that had come to dominate English ethical speculations, did not represent virtue in a way at all acceptable to the high-minded Shaftesbury. To refrain from viciousness for fear of punishment, or to practice charity from a hope of reward, did not, according to his way of thinking, constitute virtue. To be sure, the "rod and sweetmeat"[1] method would influence actions, because it "presupposed some disadvantage or benefit to accrue"; but "there is no virtue or goodness in acting from hope or fear."[2] "Thus a person loving life for life's sake, and virtue not at all, may by the promise or hope of life, or fear of death or other evil, be induced to practice virtue, and even endeavor to be truly virtuous by a love of what he practices. Yet neither is this very endeavor to be esteemed a virtue."[3] This conviction that much that passed for goodness was at least superficial, together with the obvious fact that not all religionists possessed humanity and that many atheists were wholly moral, led him to inquire as to what honesty and virtue really were. In answering this question, he gave us his theories as to Beauty and Truth, Self-love and Benevolence, man's natural goodness, and the constitution of real happiness.

That which makes a creature good, or, more exactly speaking, Goodness itself, is something beyond time and space. Neither divine legislation nor human prudence can create it, for it is immutable and eternal, existent in the very order and constitution of the universe. Indeed Beauty and Good are one and the same thing.[4] "That what is Beautiful is *Harmonious*

[1] *The Moralists*, Pt. II, sect. 2.
[2] *Inquiry concerning Virtue*, Bk. I, Pt. III, sec. 1.
[3] *Ibid.*, Bk. I, Pt. III, sect. 3.
[4] *The Moralists*, Pt. III, sect. 2.

and *Proportionable;* what is Harmonious and Proportionable, is True; and what is at once both *Beautiful* and *True,* is, of consequence, *Agreeable* and GOOD."[5] Such expressions as "beauty and good are still the same",[6] "Beauty and Truth are plainly join'd",[7] and "all Beauty is Truth"[8] are constantly recurring in his writings. "Harmony is Harmony by Nature,[9] and the most natural beauty in the world is *Honesty* and Moral Truth."[10] A convert to this theory of Beauty, than which "there is nothing so divine", Philocles resolves: "My study therefore should be to grow beautiful, in his way of beauty, and from this time forward I would do all I could to propagate that lovely race of mental children, happily sprung from such a high enjoyment and from a union with what was fairest and best."[11]

Since, therefore, Goodness and Truth are no other than Beauty and Harmony, Virtue must be a condition or state resulting from a proportion of internal affections and a relationship of these affections to the rest of the universe. In other words, Morality itself is part and parcel of that Universal Harmony so often discussed.

The affections governing man are: (1) "natural affections, which lead to the good of the public"; (2) "the self-affections, which lead only to the good of the private"; (3) "such as are neither of these nor tending either to any good of the public or private, but contrary-wise; and which may therefore be styled unnatural affections."[12]

Of these the natural affections, leading to the good of the public, are the most important; to possess them "is to have the chief means and power of self-enjoyment, and the highest possession and happiness of life."[13] "When, in general, all the affections or passions are suited to the public good, or Good of the Species, then is the natural temper entirely good."[14] In order "to deserve the name of good or virtuous, a creature must have all his inclinations and affections, his dispositions of mind

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[5] *Miscellany* III, Ch. II.
[6] *The Moralists,* Pt. III, sect. 2.
[7] *Miscellany* III, Ch. II.
[8] *Wit and Humor,* Pt. IV, sect. 3.
[9] *Advice to an Author,* Pt. III, sect. 3.
[10] *Wit and Humor,* Pt. IV, sect. 3.
[11] *The Moralists,* Pt. III, sect. 2.
[12] *Inquiry concerning Virtue,* Bk. II, Pt. I, sect. 3.
[13] *Ibid.,* Bk. II, Pt. II, sect. 1.
[14] *Ibid.,* Bk. II, Pt. I, sect. 5.

and temper, suitable, and agreeing with the good of his kind, or of that system in which he is included, and of which he constitutes a part."[15]

And what is more, these *natural affections*, as the name implies, are wholly consonant with the constitution of man. " 'Tis no more natural for the stomach to digest, the lungs to breathe, the glands to separate juices"[16] than for man to have an affection towards the good of the species. Generation and the care and nurture of the offspring are no more natural to man than is society, without which he cannot ever subsist.[17] The very helplessness of the human infant forces us "to own that he is purposely, and not by accident, made rational and sociable."[18]

By this closely concatenated logic he arrives at the conclusion, already premeditated, that man is naturally good. Although certain unnatural affections or disproportions may have destroyed the original harmony of his make-up, yet is he again perfectible. The *Characteristics* are replete with sententious statements to this effect. I choose rather to draw from his *Preface* to Dr. Whichcote's *Selected Sermons* (1698), partly because its content is not easily accessible and is, therefore, little known, and partly because one can see therefrom how early this doctrine had become an essential part of his system.[19]

Herein he attacks Hobbes roundly for having forgotten to mention kindness, friendship, sociableness, love of company and converse, and natural affection when he reckoned "up the passions or affections by which men are held together in society, live in peace, or have any correspondence one with another." "So much less *Good-nature* has he left with mankind, than what he allows to the worst of beasts". With caustic banter he assails Religion, "where love is chiefly enjoyed, where the heart is expressly called for......where charity or kindness is made all in all", for degrading the principle of Good-nature and referring all to reward, "as if Good-nature and religion were enemies." Having quoted from Dr. Whichcote, he

[15] *Ibid.*, Bk. II, Pt. I, sect. 1.
[16] *Ibid.*, Bk. II, Pt. I, sect. 1.
[17] *The Moralists*, Pt. II, sect. 4.
[18] *Ibid.*
[19] For a more extended reference concerning the relationship of Whichcote and Shaftesbury, see *The Significance of Shaftesbury in English Speculation*, P. M. L. A. Vol. XXXVIII, pp. 183-189.

adds: "Thus speaks our excellent Divine, and truly Christian Philosopher; whom, for his appearing thus in defence of *Natural Goodness,* we may call *the Preacher of Good-nature.*"

Although first place is given to the Natural or Benevolent affections, the self-affections are by no means forgotten. The propagation and preservation of the individual is necessary if there is to be any species. However, "By having self-passions too intense or strong, a creature becomes miserable."[20] An exaggerated amount of affection towards private good leaves less room for public good; but a proportionable amount is wholly desirable. "To be well affected towards the public interest and one's own is not only consistent but inseparable."[21] By the very nature of things it is "according to the private interest and good of everyone to work toward the general good."[22] In fact the general good and the private good are one and the same.[23]

The upshot of the whole matter is that the real happiness of man consists in "that self-enjoyment which arises from a consistency of life and manners, a harmony of affections, a freedom from the reproach of shame and guilt, and a consciousness of worth and merit with all mankind, our society, country, and friends — all which is founded in virtue only."[24] To be thus "is to live according to Nature, and the dictates and rules of supreme wisdom. This is morality, piety, and natural religion."[25]

What has gone before may be summarized, and what is to follow below may be outlined thus:

A. Goodness or Virtue, in no wise dependent upon action performed from hope or fear, is identical with Truth, Beauty, and Harmony and leads directly to the highest happiness.

B. Man by his original constitution is possessed of a Good-nature. Therefore the Benevolent affections, paramount to Virtue, are natural. Although the unnatural affections may gain temporary ascendency, man is perfectible. There is no real conflict between the self-affections and the benevolent ones.

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[20] *The Moralists,* Bk. II, Pt. II, sect. 2.
[21] *Ibid.,* Bk. II, Pt. I, sect. 1.
[22] *Ibid.,* Conclusion.
[23] *Enthusiasm,* sect. 5.
[24] *The Moralists,* Pt. III, sect. 3.
[25] *Inquiry concerning Virtue,* Bk. II, Pt. II, sect. 1.

A.

The philosophy of Locke, in as far as it made the criterion of action to rest in the will and law of God and made God a chief-justice dispensing rewards and inflicting punishments with impunity, was so consistent with the current theology and, consequently, so firmly rooted in the English consciousness, that to upturn it would seem not only Herculean but also impossible. The *dies irae* had such salutary effects upon the actions of frail man and was so capable of vivid portrayal that it was a favorite with both preachers and poets. Milton and Sherlock, Boyse and Berkeley, to mention but four, were stout in their defense of morality based on law and judgment. Sometimes the pragmatic, sometimes the prudential argument was advanced. To be sure, innocence suffers, virtue bleeds, saints and sages perish as victims of tyrannic rage, and vice goes uncorrected;[26] but the day of judgment comes rushing on,

> Where men and angels shall to audit come,
> And millions yet unborn receive their doom!
> Then shall fair Providence, to all display'd,
> Appear divinely bright without a shade;
> In light triumphant all her acts be shown,
> And blushing Doubt eternal Wisdom own![27]

Leland maintained that "if scripture had only contained fine and elegant discourses on beauty and virtue, and the deformity of vice, instead of proposing the sanctions of eternal rewards and punishments, it would neither have been so becoming the majesty and dignity of the supreme legislator, nor so well fitted to answer the end of a revelation designed for common use." Shaftesbury "had done very wrong in throwing out so many insinuations against the doctrine of future retributions."[28]

The potency of Shaftesbury's ethical teachings is well attested by the fact that so high a churchman as Bishop Butler seconds him in his transference of the moral guide to the individual. Shaftesbury's "moral sense" was inadequate for Butler, but the "conscience" which the latter postulated was also in opposition to the guides proposed by Hobbes and by Locke.

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[26] See forthcoming articles, by the present writer, entitled *Shaftesbury and Optimism* and *Shaftesbury and Moral Sense.*

[27] Samuel Boyse, *The Deity* (1739).

[28] *Deistical Writers,* Vol. I, p. 55.

Shaftesbury's doctrine that both God and man were blasphemed by an insistence on the hopes and fears of a future state elevated virtue to the highest pinnacle of idealism. That which Akenside characterized as "the applauding smile of heaven"[29] is a much less utilitarian and less sordid reward than that which was held out by the orthodox. Virtue thus becomes its own reward, or as Grove put it in the Spectator, "The conscience of approving one's self a benefactor to mankind is the noblest recompense for doing so."[30] Compared to this, Young's attitude seems commercial.

Rewards and punishments make God ador'd;
And hopes and fears give conscience all her powers.[31]

Nichols records the fact that Browne in his *Essays on the Characteristics* had said that "one of the followers of Lord Shaftesbury (and referring to the Author of *Philemon to Hydaspes*) had affirmed in still more emphatic expressions, if possible, than his *Master,* that *the height of Virtuosoship is Virtue.*"[32]

Butler admits without a qualm that Shaftesbury "has shown beyond all contradiction, that virtue is naturally the interest or happiness" of mankind.[33] After discussing riches, blood, greatness, and their kind, Pope concludes:

Know then this truth, enough for man to know,
Virtue alone is happiness below.[34]

Elsewhere he pictures virtue's prize as that calm sunshine of the soul, that heartfelt joy which nothing earthly can either give or take away.[35] Fielding, who is at heart opposed to all sentimental doctrines, is, naturally, averse to this thesis that virtue brings happiness. He brings odium upon it by having Square espouse the cause of "the true natural beauty of vir-

[29] *Pleasures of the Imagination,* Bk. I, l.166.
[30] *Spectator* 588.
[31] *Night* VII.
[32] *Literary Anecdotes,* Vol. V. pp. 568-569. The author referred to is Henry Coventry, whose death interrupted the Sixth Dialogue. The five Dialogues were republished in one volume in 1753.
[33] *Preface to Sermons,* 1729, sect. 20.
[34] *Essay,* Ep. IV, ll. 309-310.
[35] *Ibid.,* ll. 167-169. Compare with the references given above James Cawthorn's *The Equality of Human Conditions* (1746). Here the comparison is not so much between the virtuous and the wicked as between the high and the low, the rich and the poor. The conclusion is that the ills and pleasures knock alike at every door.

tue",[36] and by proceeding to hold him up as an object of derision because he neglected religion and "utterly discarded all goodness of heart."[37] According to the formula that virtue brings happiness, the hero, who "was acting the most virtuous part imaginable" should have been happy indeed; but he was not. "This therefore would seem an exception to the above rule, if indeed it was a rule; but as we have in our voyage in life seen so many other exceptions to it, we choose to dispute the doctrine on which it is founded, which we don't apprehend to be Christian, which we are convinced is not true, and which is indeed destructive to one of the noblest arguments that reason alone can furnish for the belief in immortality."[38] Later in the same chapter he dismisses it with an air of finality as "a very handsome and comfortable doctrine, and to which we have but one objection, namely, that it is not true." To this Dr. Johnson would say *amen.*

In estimating the force which Shaftesbury exerted upon the ethical speculations of his century, and consequently, upon literature itself, we cannot lose sight of his identification of Beauty and Truth, Harmony and Virtue, Proportion and Goodness. To trace the reflections of this union definitively would be to repeat much of the treatment of Universal Harmony and Natural Religion given elsewhere.[39] It will suffice here, therefore, if but a few pertinent examples are presented.

Among the philosophers, Hutcheson is easily the most ardent follower of Shaftesbury in emphasizing the analogy between beauty and virtue,[40] and Berkley is, perhaps, as caustic as any of his adversaries.[41] In literature the phrase "Beauty is truth, truth beauty", or its equivalent, which we are wont to associate with Keats,[42] is variously but frequently repeated, especially by the poets of the Shaftesburian school proper. Brooke identifies the "paths of Beauty and of Truth",[43] and speaks of the "Beauty

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[36] *Tom Jones,* Bk. III, Ch. 3.

[37] *Ibid.,* Bk. III, Ch. IV.

[38] *Ibid., Bk.* XV, Ch. I.

[39] See C. A. Moore, *Shaftesbury and the Ethical Poets,* P. M. L. A., Vol. XXXI, 264-325; Lyons, *Shaftesbury's Ethical Principles of Adaptation to Universal Harmony,* New York, 1900.

[40] See *An Inquiry into the Original of our Ideas of Beauty and Virtue* (1725).

[41] See *Alciphron,* Dial. III.

[42] See *Ode on a Grecian Urn,* ll. 49-50.

[43] *Universal Beauty,* Bk. IV, l. 351.

of Love, and Symmetry Divine."[44] His fragmentary poem *Conrade; the song of the Filea of Ancient Days,* reminiscent of that primitive life idealized in sentimental literature and Ossianic in mood, begins—

What do I love—what is it that mine eyes
Turn round in search of — that my soul longs after,
But cannot quench her thirst? — 'Tis Beauty, Phelin!
I see it wide beneath the arch of Heaven.

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At my heart I feel
Its potent grasp, I melt beneath the touch,
When the tale pours upon my sense humane
The woes of other times! What art thou, Beauty?
Thou are not color, fancy, sound, nor form —
These but the conduits are, whence the soul quaffs
The liquor of its Heaven. — Whate'er thou art,
Nature, or Nature's spirit, thou art all
I long for.

Cooper acknowledges his indebtedness to Shaftesbury in the *Design* prefixed to *The Power of Harmony.* To quote from his own words: "This then is the design of the poem, to show that a constant attention to what is perfect and beautiful in nature will by degrees, harmonize the soul to a responsive regularity and sympathetic order." "For what is virtue but a just regulation of our affections and appetites to make them correspond to the peace and welfare of society? so that good and beauty are inseparable." In the poem itself the soul, through habitual intercourse with the charms of things external,

Is harmonized within, till all is fair
And perfect; till each mortal pow'r perceives
Its own resemblance, with fraternal joy,
In ev'ry form complete, and smiling feels
Beauty and Good the same."[45]

The mention of two others, Akenside and Harris, must suffice. Again each can best speak for himself; hear the former:

Thus was Beauty sent from Heaven,
The lovely mistress of truth and good
In this dark world: for truth and good are one,
With like participation.[46]

[44] *Ibid.,* Bk. II, l. 333.
[45] Bk. II.
[46] *Pleasures of the Imagination,* Bk. I, ll. 372-376.

Commenting upon the passage, in a note where he mentions the *Characteristics,* he says among other things that "all rational beings must perceive beauty in certain proportions, and deformity in the contrary", and that "Beauty is founded on the universal and unchangeable law of truth." The intellectual kinship of James Harris is not to be discounted by the fact that he was a nephew of the Third Earl. In *Concord* (1751) he says:

'Ere yet creation was, ere sun and moon
And stars bedeck'd the splendid vault of heaven,
Was God; and God was Mind; and Mind was Beauty,
And Truth, and Form, and Order.

B.

This elevated virtue individually applied meant, as has been said, a certain relation of affections, of which the benevolent ones were to predominate. If one may judge historically, the age to which this new message came was sadly in need of just such a basis of ethics. Despite the Golden Rule and the example of the Good Samaritan, the church in spirit had remained strangely smug and unsocial. To be sure it had its organized charities, but the general run of religion was prudential rather than philanthropic. Conformity to dogma rather than the discharge of duties to society was too frequently the norm of virtue; the letter outshone the spirit of conduct. The church, not blind to the inequalities and injustices of life, trusted to the eternal justice of the ages to make the crooked appear straight and to render the rough places plain; to do otherwise, it argued, was to rob religion of one of its chiefest proofs of the hereafter. The complacency thus engendered had been notoriously deficient in the promotion of those social amenities which alone could ameliorate the ills of life.

The philosophy of Hobbes, and later of Mandeville, which made man by nature a compound of evil passions, rendered the perfectibility of mankind not only more chimerical but also less desirable. Thereby it was hand in glove with that torpidness begotten of a belief in the efficacy of the next world to rectify all of the irregularities of this one. Manichaeism and cynicism, while heightening the conflict within man's own breast, did not lend encouragement to social reform.

The enfranchisement of human nature by the Cambridge Platonists, such as Dr. Whichcote, and by the deists, gave an entirely different complexion to benevolence. If, as Shaftesbury insisted, man was by nature good, his complete regeneration became wholly possible and supremely desirable. It is to this old, yet new doctrine that we must look for the philosophical impulse and motivating force back of that flood of social reform that was soon to characterize the activity of the century.

Fielding has represented the humanistic and the sentimental attitudes toward human nature in Thwackum and Square. "Square held human nature to be the perfection of all virtue, and that vice was a deviation from our nature, in the same manner as a deformity of the body is. Thwackum, on the contrary, maintained that the human mind, since the fall, was nothing but a sink of iniquity, till purified and redeemed by grace...... The favorite phrase of the former, was the natural beauty of virtue; and of the latter was the divine power of grace. The former measured all actions by the unalterable rule of right, and the eternal fitness of things; the latter decided all matters on authority."[47] The general practice of Fielding, and the following passage from a subsequent chapter make his own point of view clear. "If thou dost delight in those models of perfection, there are books enow written to gratify thy taste; but as we have not, in the course of our conversation, ever happened to meet with any such person, we have not chosen to introduce any such here. To say the truth, I a little question whether mere man ever arrived at this consummate degree of excellence."[48] In the second part of the *Fable of the Bees,* Cleomenes, representing Mandeville, opposes Horatio, a follower of Shaftesbury, by insisting on the corruption of human nature and the impossibility of virtue. Swift too was convinced of the perverseness of the race. Here is Jove's address in his *Day of Judgment.*

"Offending race of human kind,
By nature, learning, reason blind;
You who through frailty stept aside,
And you who never fell — from pride;
You who in different sects were shammed,
And come to see each other damned
(So some folks told you, but they knew
No more of Jove's designs than you) —

[47] *Tom Jones,* Bk. III, Ch. 3.
[48] *Ibid.,* Bk. X, Ch. 1.

The world's mad business now is o'er,
And I resent these pranks no more —
I to such blockheads set my wit!
I damn such fools! Go, go, you're bit."

Abundant supplementary evidence is furnished by those sordid pictures in *Gulliver's Travels.* Both in his essays and in *Rasselas* Dr. Johnson has given us his answer to the much moot question. At no time does the prince find human nature to be all that might be desired; the idealistic philosopher is unintelligible, the hermit has not solved the riddle, and the people of the cities are by no means worthy of a nimbus. Wesley, Young, and Cowper are one with the poet of the *Anti Jacobin* in insisting on the necessity of "moral truth" and "Gospel law".

To set in array here the names and sentiments of all those who, with Shaftesbury, held to the theory of the natural goodness of man, would be to repeat the names and doctrines of all of those believers in deistical ideas, natural religion, and a golden age in the past spoken of elsewhere; from this the reader will be spared. What will be helpful to us, however, in casting up a final account of the literary potency of this idea, will be to keep in mind the nature of the encouragement that it gave to personal activity and aspiration. No man can long believe in the essential goodness of human nature without including his own self in that humanity which he believes to be perfectible. This means not only that he will be more beneficent in his relations with others, but also that he will be more indulgent with his own infallible self. Sweet sensibility and individual inclination are then easily substituted for common sense, education, conscience, and restraint. Unwitting of the ultimate outcome of his doctrines, the high-minded Shaftesbury believed in mankind because he believed in the naturalness of the benevolent affections, than which none could be more desirable. None, without doubt, would have regretted the prostitution of his lofty notions more than himself, had he lived to witness the results; but this does not exonerate him from the rôle that his ideas assumed. Divorced from their intended ends, they became an incentive to that mawkishness and lachrymosity which spilled itself on the pages of all too many works. Nor was this the only insidious by-product of a belief in man's native worth; a kind of *laissez faire* doctrine must also be laid at its door. Some who doubt that man was ever ordained for complete happiness, advocate that he should throw restraint to the winds and be as happy as he can.

"O Education, ever in the wrong,
To thee the curses of mankind belong;
Thou first great author of our future state.
Chief source of our religion, passions, fate:
On every atom of the doctor's frame
Nature has stampt the pedant with his name;
But thou hast made him, (ever wast thou blind)
A licensed butcher of the human kind.

Then, friend, let inclination be thy guide,
Nor be by superstition led aside."[49]

To turn from a consideration of man's natural goodness to a study of the naturalness of the benevolent affections is to turn from one page to the next in the same book. Those who regard them as part of man's constitution are many, those who look upon their exercise as pleasurable are more, and those who consider them natural, pleasurable, and paramount are legion. By way of escape from the nightmare of Mandeville, even many of the orthodox and humanists join hands with the sentimentalists. Butler agrees that at least a part of man's instincts lead "most directly and immediately to the good of the community."[50] and that "There is a natural principle of benevolence in man; which is in some degree to *society,* what *self-love* is to the individual. And if there be in mankind any disposition to friendship; if there be any such thing as compassion, for compassion is momentary love; if there be any such thing as the parental or filial affections; if there be any affection in human nature, the object and the end of which is the good of another; this is itself benevolence, or the love of another. Be it ever so short, be it in ever so low a degree, or ever so unhappily confined; it proves the assertion, and points out what we were designed for, as really as if it were in a higher degree and more extensive."[51] In answer to those philosophers who deny that there is any such thing as love, and who "some years since very much alarmed the world, by showing that there were no such things as virtue and goodness really existing in human nature, and who deduced our best actions from pride", Fielding main-

[49] Thomas Chatterton, *Happiness* (1770).
[50] *Preface,* sec. 13.
[51] *Sermon I, On Human Nature,* sect. 4.

tains that "there is in some (I believe in many) human breasts a kind of benevolent disposition, which is gratified by contributing to the happiness of others. That in this gratification alone, as in friendship, in parental and filial affection, as indeed in general philanthropy, there is a great and exquisite delight."[52] The Reverend Henry Grove, writing in the Spectator,[53] speaks of an "innate propension to beneficence", of this inclination as of "the original growth of the heart of man", and of "a natural instinct prompting men to desire the welfare and satisfaction of others." "The pity which arises on sight of persons in distress, and the satisfaction of mind which is the consequence of having removed them to a happier state, are instead of a thousand arguments to prove such a thing as disinterested benevolence."

Without dwelling upon the obvious attitude of those who were strictly sentimental toward the naturalness of benevolence, we may pass at once to some of these numerous recommendations for its practice. Some of the poems which enjoin pity, mercy, compassion and charity, by their very phrases betray their Biblical inspiration; of these John Byrom's *On Works of Mercy and Compassion* and *Verses Designed for an Infirmary* may be taken as representative. Even so, they must be read in the light of the compromise which a new philosophy had forced upon a staid theology. Other poems which present simple, sympathetic pictures of persons whom misfortune has overtaken, and which attempt to soften the hearts of superiors to the amelioration of hardships can be mentioned by title only; such are *The Chelsea Pensioner* and *The Debtor* by Sir John Henry Moore, *The Poor Man's Prayer* by Rev. Dr.Roberts, and the anonymous *The Beggar*.[54]

Certain other poems, which by acknowledgement or implication are indebted to Shaftesbury, call for a more detailed treatment.

James Thomson has already appeared so frequently in studies of this nature that nothing additional is required to establish his indebtedness to Shaftesbury.[55] But the specific mention

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[52] *Tom Jones,* Bk. VI, Ch. I.
[53] Nos. 588 and 601 for September 1, 1714 and October 1, 1714.
[54] Conveniently found in *Fugitive poetry,* Vol. IX.
[55] See P. M. L. A., Vol. XXXVIII, p. 189, note 67.

which the former makes of the latter, because of the especial appropriateness of the subject matter, may be quoted here.

> The generous Ashley thine, the friend of man;
> Who scanned his nature with a brother's eye,
> His weakness prompt to shade, to raise his aim,
> To touch the finer movements of the mind,
> And with the moral beauty charm the heart.[56]

David Mallet, in turn, in a poem entitled *To Mr. Thomson, on his publishing the second edition of his poem called Winter,* refers to the author of the *Seasons* as "Virtue's friend". We may safely say that in no way is Thomson nearer to Shaftesbury than in the encouragement that he gave to benevolence and reform. In this he occupies the position of a pioneer in the poetry of the century. Such expressions as "the ineffable delight of sweet humanity",[57] "the love .... of human race", "the sigh for suffering worth", "the awakened throb for virtue", "the sympathies of love", "all the social offspring of the heart",[58] and the "general good" abound in his pages. He calls upon the masters to be kind to those laborers who sink them "soft in elegance and ease" and speaks of "that sparing board" which covers theirs in "luxury profuse."[59] The thought of the widow starving in solitude with her orphans, while in the palace luxury strained her thoughts to create unreal wants, haunted his sense of justice.[60] "The gay licentious proud" little thought, as did he, of the "shameful variance betwixt man and man", of those who "pine in want, and dungeon-glooms", of those beset with misery, poverty, and "all the fiercer tortures of the mind".

> Thought fond man
> Of these, and all the thousand nameless ills,
> That one incessant struggle render life,
> One scene of toil, of suffering, and of fate,
> Vice in his high career would stand appalled,
> And heedless rambling impulse learn to think;
> The conscious heart of charity would warm,
> And her wise wish benevolence dilate;
> The social tear would rise, the social sigh;
> And into clear perfection, gradual bliss,
> Refining still, the social passions work.[61]

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[56] *Summer,* ll. 1551-1555.
[57] *Summer,* ll. 892-893.
[58] *Autumn,* 1019 ff.
[59] *Autumn,* ll. 350-359.
[60] *Winter,* 1057-1060.
[61] *Ibid.,* 322-358.

An exceedingly vivid picture of the gloomy jail and all of its injustices is given, and that "generous band", the Jail Committee of 1729, is commended for its activity. The "sons of Mercy" are then called upon to resume the search, to "drag forth the legal monsters" who "lengthen simple justice into trade", and to usher in the day when every man will be "within the reach of right."[62] Elsewhere he espouses the cause of the Foundling Hospital[63] and the founding of Georgia for debtors,[64] and denounces the slave trade.

Pope, though less concrete and picturesque than is Thomson, is one with him and Shaftesbury on the subject of benevolence. The very helplessness of the human babe is proof that man by nature was meant to be a social being.[65]

> Heav'n forming each on other to depend,
> A master, or a servant, or a friend,
> Bids each on other for assistance call,
> 'Till one man's weakness grows the strength of all.[66]

Every thing in the universe works toward "the general good", not "the good of one, but all",[67] and the good instinctively realize that faith, law, and morals

> "All end in the love of God, and love of man."[68]

Both Brooke and Harris find the social nature of man eloquently exemplified in the relationships existing between the members of the lower creations.[69] To the latter, man's chief joy comes when he "feels affection melt the social heart". To Cooper a "beautiful action" is synonymous with "the generous resignation of private advantage by some individual, to submit and adopt his single being to the whole community, or some part of it."[70] Having spoken of the necessity of an internal order of manners, and before passing on to "public transports" which shall inflame the soul, Melmoth acknowledges his allegiance to Shaftesbury with these lines:

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62 *Ibid.*, 359-388.
63 *Liberty*, Pt. V, ll. 471-483, 647-666.
64 *Ibid.*, ll. 638-646.
65 *Essay*, Ep. III, ll. 131-138.
66 *Ibid.*, Ep. II, ll. 249-254.
67 *Ibid.*, Ep. III, ll. 7-14; Ep. IV, ll. 35-38.
68 *Ibid.*, Ep. IV, ll. 330-340.
69 *Universal Beauty*, Bk. V, ll. 330-339; *Concord.*
70 *Design* prefixed to *The Power of Harmony.*

Fir'd by this thought great Ashley, gen'rous sage,
Plann'd in sweet leisure his instructive page.[71]

Whitehead's Enthusiast, having decided upon a life of contemplation in solitude is rebuffed thus:

And is not thy o'erflowing mind
Unless thou mixest with thy kind,
  Benevolent in vain?

Enthusiast, go; try every sense:
If not thy bliss, thy excellence
  Thou yet hast learn'd to scan.
At least thy wants, thy weakness know;
And see them all uniting show
  That man was made for man.[72]

Grainger begins *To Solitude* (1755) in the true Wartonian manner, but is soon told that he owes his life and knowledge to his fellow creatures, and that

The height of virtue is to serve mankind.

Soame Jenyns in *An Essay on Virtue* (1734), to which Johnson took exception, reasons that

The common welfare is our only task.

If men could but realize this, and

. . . . . that one good-natur'd act more praises gain,
Than armies overthrown, and thousands slain:
No more would brutal rage disturb our peace,
But envy, hatred, war, and discord cease;
Our own and other's good each hour employ,
And all things smile with universal joy;
Virtue with happiness her consort join'd,
Would regulate and bless each human mind,
And man be what his maker first design'd.

John Langhorne has two poems that ring to the same tune. In a *Country Justice* (1774) he makes an appeal for justice to vagrants, the poor, and the like; and in his *Hymn to Humanity* shows real sentimentality by wishing for the "sympathetic glow", the "feeling breast", and "the tear humane". To add but one other example to this prolix list, monotonous because of the painful similarity of subject matter, mention only need be made of Cowper's vigorous attack upon slavery.[73]

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[71] *Of Active and Retired Life.*
[72] *The Enthusiast.*
[73] *The Task,* Bk. II, ll. 29-47.

It will be remembered that Shaftesbury, in opposition to Hobbes, insisted that there was no conflict between the good of the individual and the good of the species; this became a favorite theme with his successors.

Butler, with remarkable iteration, insists upon the harmony of the two. The happiness of the individual and the good of society "do indeed perfectly coincide; and to aim at public and private good are so far from being inconsistent, that they mutually promote each other."[74] "Duty and interest are perfectly coincident."[75] "The chief design of the eleventh Discourse is to state the notion of self-love and disinterestedness, in order to show that benevolence is no more unfriendly to self-love than any other particular affection whatever."[76] In sermonic literature the idea is given faithful repetition by Hurd.[77] The Reverend Henry Grove in the first of his two contributions to the Spectator, the year after Shaftesbury died and in the same year as the appearance of the second edition of the *Characteristics*, asks: "Is the force of self-love abated, or its interest prejudiced by benevolence?" His answer is: "So far from it, that benevolence, though a distant principle, is extremely serviceable to self-love, and then doth most service when 'tis least designed."[78]

Pope gives surprising care to the establishment of the principle. He introduces it in one form or another in at least three out of the four parts of the *Essay*, closes Epistle III with a statement of the identity of "self-love and social", and includes the same formula at the end of the poem as standing for one of its chief purposes.[79] To be sure Pope might have had the doctrine from Bolingbroke,[80] but both Bolingbroke and Pope may just as well have had it from Shaftesbury.[81]

By no means is it to be understood that all of the "benevolent

[74] *Sermon I,* sect. 3.

[75] *Sermon II,* sect. 13.

[76] Quoted from the *Preface,* sec. 29.

[77] See *Works,* London, 1811, Vol. VI, pp. 132-133.

[78] *Spectator* 588.

[79] See *Essay,* Ep. II, ll. 53-60, 87-88; Ep. III, ll. 147-160, 307-318; Ep. IV, ll. 353-354, 361-372, 393-398.

[80] See Leland, *Deistical Writers,* Vol. II, pp. 32-34, where references are made to Bolingbroke's *Works* as follows: Vol. IV, p. 282; Vol. V, Third of his *Fragments* and *Essays,* and pp. 79, 82, 98, 115.

[81] The writer has in the process of preparation an article dealing with the doctrines of Pope's *Essay on Man* and those of other writers, particularly Shaftesbury.

literature" of the century was written by avowed deists, any more than it is to be thought that the reforms were actually carried on by the abstract philosophers. The orthodox, beset by Shaftesbury on the one hand and made ashamed by Mandeville on the other, were driven from cover and undertook with remarkable vigor the curing of many of the social ills. Once awake to their full obligations to their fellows, they found, to be sure, all of the justification and exhortation that they needed for such works in their own scriptures. But it is to Shaftesbury and to his most ardent disciple, Hutcheson, that we must look for the introduction of an insistence upon the principle of benevolence in English ethics. As the father of the "Benevolent Theory of Morals", Shaftesbury must be given large credit for the introduction and growth of humanitarian ideals.

There is abundant historical evidence that the preachments of the benevolists did take root. If we are to seek a literary statement of this fact, we may again turn to Fielding and Johnson. The former observed that "the amiable characteristic of this age is charity." Three days later he tried to show "the most effectual, best, and cheapest methods of exerting charity"; and in the course of the next two days remarked: "Amongst other species of charity, for which this age is justly celebrated, there is one which shines forth in a very particular manner, I mean the founding of hospitals."[82] Almost twenty years later Dr. Johnson observed: "But no sooner is a new species of misery brought to view, and a design for relieving it professed, than every hand is open to contribute something, every tongue is busied in solicitation, and every art of pleasure is employed for a time in the interest of virtue.......The most apparent and pressing of miseries incident to man, have now their peculiar houses of reception and relief."[83]

The insincerity on the part of the benevolists insinuated in the accusation that "they were all tenderness in words" and that "their finer feelings evaporated in the moment of expression"[84] can by no means be maintained with accuracy against Shaftesbury, who was conspicuous for the succor which

[82] *The Champion,* Feb. 16, 19, 21, 1739-40.
[83] *The Idler,* No. 4, May 6, 1758.
[84] Made by Edmund Malone, and cited by Moore, p. 316, from *Life of Edmund Malone,* London, 1860, p. 427.

he gave to needy students and for the vigor with which he espoused the cause of the oppressed while he was yet in public life. That philanthropy should have become a fashion is a compliment to the popularity of the cause, rather than an opprobrium upon the doctrine. It seems universally natural that some will affect to be what others actually are. Hypocrisy is the normal companion of English prudery, and posturing, apparently, became the accompaniment of benevolence. But the most of us would prefer modesty and sympathy to license and social coldness, even though their possession does entail a modicum of dissimulation.

Such poems as are spoken of below, while directly pointing to the existence of feigning and pretense in morals, indirectly attest the widespread popularity of practices that came to be fashionable. Joseph Warton in *Fashion* has the parsimonious Chremes unlock "his triple-bolted box" to the poor, not because he has any compassion of heart or impulse to good, but because "his neighbors gave". Robert Lloyd vents his righteous hatred against those

Who make all public good a trade,
Benevolence a mere parade,
And Charity a cloak for sin,
To keep it smug and warm within.[85]

Similar sentiments are expressed by T. W. Gent, in *The Country Priest,* Christopher Smart in *Generosity* and *Connoisseur,* and by Wm. Kendrick in *On Moral Sentiment.* The general hypocrisy of the times is vividly portrayed by Robert Dodsley in a poem addressed to Mr. Pope and entitled *On Good and Ill-Nature.*

Good-nature now has changed her modest face,
For smiling flattery, compliment, grimace:
Fool grins at fool, each coxcomb owns his brother,
And thieves and sharpers compliment each other.[86]

Another type of benevolence to which Shaftesbury's philosophy could not help but give encouragement is that which the poet of the *Anti Jacobin* calls "French Philanthropy", and which leads a man to become a "friend of every country but his own." Not that the ardent Ashley was not a patriotic English man — no charge could have less foundation. But a philosophy

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[85] *Charity, A Fragment. Inscribed to the Rev. Mr. Hanbury.*

[86] A complimentary picture of what good-nature was previously thought to be precedes these lines. See also Christopher Smart, *On Good-Nature.*

which included even the vegetables and the beasts in its system of Universal Harmony could hardly be circumscribed by geographical limits. The very phrase which the anti-Jacobinist uses to describe this philanthropy, so invidious to him — "the general love of all mankind"[87] — bears such a close resemblance to expressions already noted as to make it certain that Englishmen did not have to learn from revolutionary France that doctrine of universal democracy which permeates the literature of the last decade or two of the century.

It remains for us to notice one other obvious by-product of the doctrines and tendencies that we have been considering. The rhapsodic contemplation of nature as a religious necessity, the belief in man's natural goodness and his possession of a "moral sense", and the exercise of the benevolent passions as the highest manifestation of virtue, were potentially capable of giving a tremendous impetus to the enjoyment of feeling. By his own theory, virtue, to Shaftesbury, was its own reward, and there was coincident to vice a kind of inner repulsion that was anything but pleasurable. That he meant thereby to suggest the performance of virtuous acts, the exercise of compassion, and the dispensing of benefactions for the sake of the titillative reaction would be unthinkable, so chaste and austere was his conception of virtue; but that he did in reality give abetment to the cultivation of the feelings for their own sake is beyond peradventure. Here we are not in the realm of speculation as to what might well have been the case; the actual statements of many of those whom we have learned to place in the Shaftesburian school testify to a sweet pleasurableness which was more than fortuitous. Just as the contemplation of nature, abstracted from moral motives, came to be indulged in because of the sensuous gratification that it was capable of producing, so the exercise of the benevolent affections, divorced from social ends, came to be the habit because of the compensating mood which such a performance induced.

Grove, a Presbyterian minister, speaks of the "charming delight which immediately follows the giving of joy to another, or relieving his sorrows; this, "when the objects are numerous, and the kindness of importance", is "really inexpressible."[88]

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[87] *Anti Jacobin*, XXXVI.
[88] *Spectator* 588.

How, to distemper'd thought,
Does virtue in mild majesty appear
Delightful, when the sympathetic heart
Feels for another's woes!

exclaims Cooper.[89] One of the specific contentions of Akenside is that "All the natural passions partake of a pleasing sensation."[90] Ask the faithful youth who mourns for his departed lover why he clasps her urn so frequently and in solitude pays her tribute of his tears, and

......he will tell thee, that the wealth of worlds
Should ne'er seduce his bosom to forego
That sacred hour, when, stealing from the noise
Of care and envy, sweet remembrance soothes
With Virtue's kindest looks his aching breast,
And turns his tears to rapture.[91]

Why do all of the inhabitants of the village climb the neighboring cliff to watch the helpless victims in some bark as they are killed by the pitiless sea? Why does Pity melt their eyes and Terror seize them?

O! deemest thou indeed
No kind endearment here by nature given
To mutual terrour and Compassion's tears,
O'er all the edge of pain, the social powers
To this their proper action and their end?[92]

John Armstrong, who complimented Shaftesbury by saying that he had "turn'd more solid heads than one,[93] in a poem called *Of Benevolence* (1751) is free to recognize the thrill that is the accompaniment of generous activity.

To do, possess'd with Virtue's modest fire,
Such generous deeds as we with tears admire;
Deeds that, above ambition's vulgar aim,
Secure an amiable, a solid fame;
These are such joys as Heaven's first favorites seize;
These please you now and will forever please.

Almost innumerable parallels could be added, but when the humanists themselves felt no compunctions from such enjoyments, we need not argue the point.

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[89] *The Power of Harmony*, Bk. II.
[90] From the *Argument* to Bk. II of *Pleasures of the Imagination*.
[91] *Pleasures of the Imagination*, Bk. II, ll. 683-693.
[92] *Ibid.*, ll. 693-711.
[93] *Taste* (1753).

As this sweet pleasurableness of sensibility gradually insinuated itself upon the consciousness of the century, authors began, both by temperament and by design, to depict situations that contained the necessary spur to the feelings. The drama of sensibility rapidly replaced the drama of the seventeenth century which was orthodox, even though it was frequently vulgar. The doctrines of man's natural goodness and of his perfectibilily became as common on the stage as they were in the works of the deists. Sentimental Comedy and Domestic Tragedy were filled with pictures of virtue in distress. To contend that this change in the drama was due to Shaftesbury would be to support an obvious anachronism, for at least one genuine Sentimental Comedy had appeared before Shaftesbury had published anything.[94] That the philosophical justification, however, of such a drama rests upon the doctrines of natural religion can not but be vouchsafed; and that in its later development it profited greatly from the moods which deism had engendered is beyond the realm of conjecture.

This craving of the sensibilities to be gratified had its influence upon periodical literature also. Steele, whose example and practice were strong encouragement to the drama of sensibility, flooded the pages of the *Spectator* and the *Tatler* with pictures of virtue in distress.[95] The penning of these must have given his own emotional nature great bliss;[96] certainly they met with a hearty reception, for they were repeatedly imitated in one form or another.

In fiction the contemplation of situations for the sake of the thrill is likewise apparent. Both the English and French public grew impatient with Richardson for not furnishing them with an intimate analysis of the feelings of Clarissa more rapidly than he did. Sterne, by the very title of his book, brands his journey as a *sentimental* one. Mackenzie so fills *The Man of Feeling* with tears that it is all but disgusting. Despite a mental reservation as to the full propriety of his course of action, Harley gives a shilling to the beggar,[97] pities the old man who

[94] Cibber, *Love's Last Shift* (1696). See Bernbaum, *The Drama of Sensibility*, Boston, 1915, for a definition of the type and a history of its rise.

[95] As examples see *Tatler* Nos. 33, 94, 198; *Spectator* Nos. 190, 322.

[96] See *Tatler* 181 for a comment as to his temperament; also Thackery, *English Humorists*, 1864, p. 158-159.

[97] *Cassell edition*, pp. 36-37.

would not part with his counters,[98] pays "the tribute of tears" to the story of the young lady in bedlam,[99] and, moved with compassion, pawns his watch for the comfort of the woman of the street.[100] In this same connection mention ought also to be made of Goldsmith's *Vicar*. The full significance and interrelatedness of these works are realized only when we keep in mind the fact that Mackenzie was attracted to *The Sentimental Journey* while he was studying law at London, that Burns "was especially fond of Sterne's *Sentimental Journey*", and "absurdly overated Mackenzie's *Man of Feeling*,"[101] that Goldsmith's *Vicar of Wakefield* affected Goethe, and that *Clarissa* exerted a strong influence upon Rousseau.

[98] Ch. XXV.
[99] Ch. XX.
[100] Ch. XXVI.
[101] Dow's *Introduction*, p. xli.

AN EDICT OF PHILIP, BY THE GRACE OF GOD, LANDGRAVE OF HESSIA, COUNT OF CATZENELENBOGEN, DIETZ, ZIEGENHAIN AND NIDDA—HOW AND IN WHICH FORM THE JEWS FROM NOW ON SHALL BE TOLERATED AND TREATED IN OUR PRINCIPALITY AND OUR COUNTIES AND DOMINIONS. M. D. XXXIX (1539).

Translated by

ERNST VOSS

First of all the Jews shall promise under oath to our County Judges, also to the Clergymen of every place where they are domiciled not to practice any blasphemy with their people against Christ our Lord and his holy Religion, nor to tolerate such practices, but to follow faithfully that which Moses and the Prophets expected them to do, and that they will also not bother their people with the teachings of their Talmudian teachers which are not in conformity with the Law and the Prophets, in order that through these godless Talmudian writings the poor good-hearted Jews may not be first of all kept away from our own true religion.

Secondly, the Jews shall solemnly vow and promise not to erect anywhere new synagogues, but to use only the old established synagogues and to do this in all quietness.

Thirdly, the Jews shall promise to discuss with none of our Faith religion in any way or form whatever, except with those preachers which we shall appoint for that very purpose.

Fourthly, the Jews shall also solemnly promise that they will come with their women and children to hear the clergymen which we will ordain especially for them.

Fifth, the Jews shall buy and sell in a fitting manner, but only in those places where there are no guilds or where the guilds tolerate them. But they shall not sell their wares at a high cost, but at a reasonable profit, as it shall be stipulated by our officials and burgomasters, and they shall not offer for sale any wares, unless these are first permitted by our officials, burgomasters or city councils.

Sixth, the Jews shall perform all their business in an upright manner, and not carry on any illegitimate business. Whenever any Jew is convicted of carrying on such an illegitimate business, our officials shall punish him accordingly and very strenuously, that is, he will forfeit all his possessions, and he who notices such illegitimate tactics in a Jew and reports him first and on good grounds shall receive the tenth part of all the goods that are forfeited in this way.

Seventh, no Jew shall practice usury or extort money from our poor people. If, however, a Jew should loan someone a Gueldin for a year or two, this must be done in the presence of our county judges with the knowledge of our council and then according to a reasonable rate of interest, that is of a hundred gueldin for a year, not more than five gueldin or what otherwise may be customary to pay to the Christians.

If, however, a Jew should ask interest beyond this amount, he shall forfeit the capital of the money that he loaned and half of all his possessions and in addition he shall be put into the tower for four weeks.

Further no Jew shall be allowed to lend money to any man without the knowledge of his wife, nor to any woman without the knowledge of her husband and only in the presence of our judges or burgomasters and city councils. However, if this should be done in spite of all these warnings the person who borrowed the money from the Jew shall not be bound to return any of the sum to the Jew, but the Jew shall have lost the capital as well as half of his other possessions, and in addition he shall give as punishment half of the amount that he lent, to us and the other half of that sum to the officials and the burgomaster and the city council, and further he shall be put into jail for this offense for two weeks.

Eighth, the Jews shall swear on oath to God not to give any thing in the form of a present or bribe to a citizen, a governor, a member of the city council, a burgomaster or policeman or their wives, not even a penny or a penny's worth on punishment of limb and life, so that our officials may not be bribed by gifts and made more willing and lenient to overlook the illegal money transactions, the usuries and unfair dealings of the

Jews. If, however, any of our officials should accept presents from the Jews and overlook their illegal financial dealings, they will be punished without delay most surely for this misdemeanor.

Ninth, Any Jew who attacks a Christian woman or virgin shall expiate this crime with his life.

Tenth, When a Jew buys stolen goods or lends money on them, he shall be put to death for this offense. And in order that a Jew may protect himself in these things he shall not buy goods or loan money on goods before he has made proper inquiries where such goods came from and whether the person that offers them for sale or that wants to borrow money on them, has a legal right to these goods.

Eleventh: Our servants of the law, burgomasters, and members of the Council shall not under any circumstances allow a non-resident Jew to buy or sell in our lands and territories anything, be it much or little, big or small.

Twelfth: Our officials, mayors and Council members shall see to it with great industry that the Jews obey this edict in all its details.

Thirteenth: We will allow the Jews to have special persons chosen from amongst their own numbers to cooperate with our officials that the Jews honestly and faithfully observe these laws. But if any of them should offend against these laws they shall be punished according to these statutes and also according to their own laws.

Fourteenth: We expect the Jews in our territory to pay to us the Protection Money as agreed between us, everybody according to his circumstances.

Now follows the German text of this famous edict of the year 1539.

**Ordnung vnser Philip,
sen von Gottes gnaden Landtgraue
zu Hessen, Graue zu Catzenelebogen, Dietz, Ziegenhain, vnd Nidda, Wie vnd was gestalt
die Juden nun hinfuerter inn vnsern Fuerstenthumb, Graueschafften vnd gebieten gelitten vnd geduldet
werden sollen.
.M.D XXXIX**

Wfb. Qu. 190.7. 4°.

ERstlichen sollen die Juden vnsern
Amptleuten, auch den Pfarrherrn yedes orts da sie gesessen sein mit dem eyde versprechen, bey den jren keyn lesterung wider Christum vnsern herrn, vnd seine heylige Religion zutreiben, noch zu gestaten, sonder sich des allein zuhalten, dz jnen Moses vnd die Propheten vor gegeben haben, vnd das sie auch die jren mit keyner satzung jrer Talmutischer lerer, weliche dem gesetz vnd den Propheten nit gemesz seien, beschweren woellen, damit durch die Talmutischen gottlosen gedichte die armen guothertzigen Juden von vnser waren Religion, nit zuom fuernemhsten abgehalten werden.

Zum andern sollen sie die Juden geloben vnd versprechen, nirgent newe synagogen auffzurichten, sonder sich allein der alten vnd vorgebaweten mit aller stille zugebrauchen.

Zum dritten sollen sie versprechen, mit niemants der vnsern von der Religion zu disputieren inn eynigen weg,[1] dann alleyn mit denen predigern, die wir darzuo besonders verordnen werden.

Zum vierden, Das sie den Predigern, die man jnen in sonderheyt verordnen wuerdt, sampt jren weibern vnd kindern kommen vnd predig hoeren sollen vnd woellen.

Zum fuenfften, sollen zimlicher weise kauffen vnd verkauffen, doch in den stetten vnnd orten da keyn zuenffte sein, oder da sie die zuenffte leiden. Doch sollen sie jr wahr nit vertewren, sondern vm eynen zimlichen billichen pfennig geben, wie es jnen vnsere beampten oder Burgermeyster vnd Rath setzen wuerden, vnd sollen keyn wahr verkauffen, sie seye jnen dann zuuor durch vnsere beampten Burgermeister oder Rath gesetz worden.

Zum sechsten, sollen alle jre hendel auffrichtig treiben, mit keynem vngebuerlichen handel oder vinantzen vmbgehn, Wo eyner solichs vberfuere vnd vnrechte hendel triebe, den sollen vnsere beampten darumb nach gelegenheyt, vnd ernstlich straffen, nemlich mit verfallung aller seyner gueter Vnnd der so solichen falsch sehe von den Juden, am ersten vnnd mit grunde anzeygt, soll haben den zehenden pfennig von solichen verfallnen vnnd verwirckten guetern.

Zum siebenden, sollen keynen Judischen gesueche[2] oder wuecher treiben, vnd vnser arme leuthe nicht vbernemen. Wuerden sie aber eynem eynen guelden zwen oder drei oder mehr leihen, solichs solle geschehen inn beysein vnserer amptleut oder amptknecht, oder mit wissen eynes Raths, vnnd davon nach billiger widernuege der selbigen. Als nemlich von eynem

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[1] Cf. the German-American expression, corresponding to the English in any way.

[2] cf. Weigand, DWb. I, 682. mhd. der gesuoch=Erwerb, Gewinn, Geldzins.

hundert guelden eyn jar lang fuenff guelden, oder was man sunst den Christen zugeben pflegt, gegeben werden. Wuerde aber eyn Jude darueber wuocher vnd gesuoch treiben, so solle er die hauptsumma seines auszgelihenen gelts, vnd die helfft aller seiner gueter verfallen haben, vnd darzu vier wochen mit dem thurn gestrafft werden. Es soll auch kein Jude keynem man allein on vorwissen seiner hauszfrawen, Auch keynem weibe allein on vorwissen jres mannes, vnnd on beisein vnserer Amptleute, Amptkechte, oder burgermeyster vnd Raths etwas leihen. Geschehe aber solichs, so solle der jhenig so das gelt entlehenet hat vom Juden, nicht schuldig sein dem Juden was wider zugeben, Sonder der Jude soll die selbig hauptsumma sampt dem halbenteyl aller seiner gueter verlorn haben, vnd darzuo noch souil als die hauptsumma desselben gelihenen gelts gewesen, halb vns, vnd halb den beampten, vnd burgermeyster vnnd raht zu straff geben, vnnd darzuo vierzhen tage inn thurn gelegt werden.

Zum achten, sollen sie eynen eydt zuo Got schweren, keynem burger, Stathalter, Rathsamptman, burgermeyster oder diener, oder der selbigen weibern, etwz zuschencken, auch nit eynen einigen pfennig oder pfennigs werth, bei straff jres leibs vnd lebens, Damit vnsere beampten nit also durch gabe gestochen, vnd den Juden dester eh jre vinantzen, vnbillichen wuocher vnd vngepuerliche hendel gestatten vnd zuosehen. Wuerde auch darueber eyner vnser beampter geschenck von Juden nemen, vnd jre vinantzen oder vngepuerliche hendel zuosehen, der soll von vns darumb vnnachlessig gestrafft werden.

Zum Neunten, Welicher Jude eyn Christen weib oder Junckfraw schendet, oder beschlefft, den sollen vnsere beampten am leben darumb straffen.

Zum zehenden, Welcher Jude gestolen guot kaufft oder darauff leihet, den sollen vnsere beampten am leben straffen. Vnd damit sich der Jude im selbigen versehen koenne, so soll er keynem auff etwas leihen, oder das selbig abkauffen, der Jude hab sich dann zuuor erkoendigt, woher sollich guot komme. Vnd ob auch derjhenig so sollich guot verkauffen, oder darauff entlenen will solchs zuthun macht habe oder nit.

Zum eylfften, Es sollen auch vnsere amptknechte, Burgermeyster vnd Raht gantz vnnd gar keynen auszlendischen Juden gestatten oder zulassen, etwas in vnsern landen vnd gepieten zukauffen oder zuuerkauffen weder wenig oder vil.

Zum zwoelfften, sollen, vnsere beampten Burgermeyster vnnd Rath, mit fleysz darauff sehen, Das sich die Juden diser articul also gehalten.

Zum dreitzehenden, Woellen wir den Juden zulassen, das sie sonderliche personen vnnder jnen haben, die beneben vnsern Amptknechten mit zuosehen, das die Juden sich rechtschaffen, vnnd diser articul gehalten. Welcher sich aber deren nit halten wuerde, das sie den selbigen vnder sich selbst auch nach jrer satzungen straffen muegen.

Zum viertzehenden, Woellen wir haben, das sie vns den schutzpfennig geben, wesz sie mit vns vberkommen werden, vnnd sonderlich eyn yeder, nach dem er vermag.

SYNTAX OF THE ADVERB, PREPOSITION AND CONJUNCTION

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FOREWORD

The preceding publications of this (Thought and Language) series have occasionally used the current classification of words as "parts of speech", when it apparently was safe to do so for the sake of the convenience offered by its general acceptance. But those publications did, and this one will, in the main renounce that classification.

PART I. THE ADVERB

In examining the words — and also phrases — rankable respectively as adverbs or adverbial, an effort will be made to "prove all things" advanced by Grammar and "hold fast that which is good"; but, as Grammar was not always rationally guided in its evolution, but appears to have "just growed" like Topsy, the amount of what may be held fast is disappointing. Accordingly departure from the current doctrines of our grammars will be so considerable, that what must rank as merely individual opinions may as well be put as questions. First, then, the more general inquiry:

I. *On what elements of judgment may an adverb bear?*

In illustration of this topic there is need of the prepositional phrase in the adverbial function. This phrase thus functioning is recognized so generally that examination of its structure is, in this connection, hardly necessary.

That caution is advisable in answering our interrogative title, is suggested, for example, by

He ate his breakfast in his dressing gown,

in which a tendency to rank the prepositional phrases as adverbial might lead to ranking this one as adverbial to "ate", although what dominatingly was "in the dressing gown" is "He".

Analogously, in

He ate his breakfast on a tray,

the easily adverbial "on a tray" is in this illustration more appropriate to "breakfast" than to "He" or "ate".

In

He ate his breakfast hastily

the form of the final word precludes association of the haste with "He" or "breakfast", though the haste might quite as well have been the eater's; and imagination — even actual usage — meets no barrier to associating haste with "breakfast": witness General Scott's much ridiculed "I ate a hasty plate of soup"; compare with this "I took a prudent pill" etc.

In

He ate his breakfast in the kitchen

he, the eating and the breakfast, each in turn or all at once or as a unit, are appropriately enough conceivable as "in the kitchen"; and they might eitherwise — I really need this word — be intended by the maker of the sentence.

The desirability of further caution may be emphasized by some consideration of the trouble into which the lack of caution has betrayed grammarians. To use a somewhat intricate illustration, speaking of the grocers who in part supply my table, I might say with some propriety

They are rapacious.

Their rapacity may be intensified in

They are *conspicuously* rapacious.

The degree of this conspicuousness of the rapacity may be augmented as in

They are *more* conspicuously rapacious than other dealers.

The augmentation of this degree may be increased, e.g. in

They are *much* more conspicuously rapacious......

The muchness or amount of augmentation may be amplified as in

They are *extremely* much more.......

The degree of this extremeness may be reinforced e. g. in

They are *very* extremely much more.......

In feminine fashion reinforcement may be emphasized e.g. in

They are *so* very extremely much more.......

Being however in an indulgent mood, I put a "not" with "so". This "not" might ordinarily be taken with the "are", and make my statement negative. But I intend the "not" as an ouster of the "so": very much is well enough; "*so* very much" is a bit too strong; accordingly

They are *not* so very extremely much more.......

But, on reflection, absolute retraction doesn't please me, and I "hedge" the "not" with "*probably*"; and "probably" itself I temper with a modifying "*rather*", thus obtaining

9 8 7 6 5 4
They are rather probably not so very extremely
3 2 1
much more conspicuously rapacious than other dealers.

Incidentally this aggregation emphasizes, in the use of words, the weakness of excess. I've said so much, that I have hardly told you anything. But it is nearer to my purpose to observe that our grammarians presumably would rank the numbered words as adverbs, though no one of them "limits a verb". These words moreover also differ greatly in their sentence-factorships. Number one is adjunct of "rapacious", which is ranked by Grammar as an adjective. Number two is adjunct of number one—three, of two—and so on through the list; or stated more conveniently, one is the primary adjunct of "rapacious;" two, the secondary, and so on till you come to "rather" which is adjunct to "rapacious" in the ninth degree.

Moreover, starting with, for instance,

Selfish dealers often are rapacious,

probably, if we should put our wits together, we might build an ostensible sentence with nine further "adverbs" bearing on "selfish", and eight on the actual adverb "*often*". Of the thirty-one words thus assembled, twenty-seven accordingly would rank as adverbs — which suggests that if the pupil or the student is baffled by the embarrasing "What-part-of-speech-is-this?", his safest guess is "An adverb." In the present case the guess that *all* the words are adverbs would be, *fide* Grammar, 27/31 correct, or 85 on the usual hundred scale — a standing which might lay some claim to pass him on the books of teachers in a normal school, university or college.

The above affords a mere preliminary glimpse of the adverbial possibilities; for obviously an adjunct, adjectival or adverbial, not only may be primary or secondary and so forth, but may also rank as first or second — *n*th.

To illustrate, in

His lamentable and disgraceful failure

it might indeed with plausibility be claimed that "lamentable" and "disgraceful" are, by means of "and", so joined together that they operate together; and the like would hold of

He lamentably and disgracefully failed.

But in

His recent lamentable failure,

and in

He recently lamentably failed,

there's no suggestion of combining, and as neither adjunct seems to operate upon the other, there is no occasion to suggest subordinate rank of either one, by calling it secondary to the other. Since they are coordinate it is more accurate to indicate their merely earlier or later bearings, for instance on the verb, by calling them respectively its first and second adjuncts.

Now the number of coordinate adjuncts is in theory unlimited; to each of these a theoretically limitless series of successively subordinated adjuncts may be fastened; also any member of such series might be double — even multiple. Thus, in

Tradesmen are *astonishingly, unimaginably* often rapacious,

one would hardly rank the first of the italicised adverbs as an adjunct of the second. One would probably regard them as coordinate adjuncts of "often", recognizing also that each one of the two is an available point of attachment for a series of subordinate adjuncts.

Grammar recognized the insufficient scope of what is strictly meant by "ad-*verb*", and defined this part of speech as "a word that limits a verb, an adjective or another adverb." With the above suggestion of adverbial possibilities in mind, the definition seems to help us very little in foreseeing what particular role or kind of role the adverb of the dictionaries will be found to play in a given sentence — which of multitudinous possible sentence-factorships will be assigned to it. In other words we must distinguish by function, rather than by form or position in the *Satz-bau,* the ad-verb, the ad-adjective and the ad-adverb.

II. *On what constituents of verbal meaning may an adverb bear?*

For instance, given

Her gown is probably green,

my own and, I suppose, your mental process is as follows: we are started by a visual impression which, although a unit, still consists of many factors; some of these — no matter which ones or how many, but an advantageously selected and sufficient number — we express by "gown"; the color factor we express by "green". By daylight we might say "Her gown is green." But, in the uncertain artificial light of an evening gathering, we too are uncertain, realizing that the gown may after all be blue. The usual certainty of an assertion yields to probability. Accordingly the question rises: which of the judgment-elements does the probability modify?

In

He ate the apple

"He" and "apple" are exhibited in a relation which may be defined as that of eater to food. This relation would moreover not exist, if it were not established by the act of eating; and, in exhibition of relation and relation-causing act, the latter is commonly the more conspicuous.

Till relations generally, and the action-relations in particular, have been thoroughly investigated, a mere language-student will not be expected to do much toward their elucidation. As a leading thought-investigator once remarked to me, relations have remained essentially without investigation.

Briefly, then, this tentative suggestion: when an action — say an output of energy — occurs, we commonly assume an energy-exerter and an energy-endurer, or — as Grammar puts it — an actor (subject) and an object which "suffers" the act. The output of the energy (or to say the act) develops a relation; and the two in my illustration are incorporated in the meaning of a single word — a verb. Obviously then the adverb has an opportunity to choose, between at least two elements of verbal meaning, that one on which it will bear. For instance, using now a livelier illustration, given

Is it true that he was taking poison?

in the answer

He was probably taking poison

doubtless the adverbial adjunct bears on "was" in preference to "taking", as is indicated by the usual reduction of the answer, for example, to the mere

He probably was,

which indicates the minor prominence of "taking".

Given now the briefer

Is it true that he took poison?,

in the answering

He probably took poison

probability again associates itself presumably with the relation which the taking caused, although in this case there's no "was" to name relation separately. What is sauce for the goose is sauce for the gander.

But given

Was he swallowing or tasting it?,

the answer

He was probably tasting it,

exhibits probability as bearing rather on 'tasting" than on "was", as indicated by the fact that "was" may be omitted — not so, "tasting", as appears in a comparison of the utterly inadequate

He probably was

and the entirely adequate

Probably tasting.

So also, then, in answer to the question

Did he taste or swallow it?,

the words

He probably tasted it

may be assumed to pose the probability as bearing rather on the relation-causing act, than on the caused relation.

Two were killed; and one was probably fatally injured.

While the intention of this illustration might be to exhibit injury as what was probable, it seems more plausible that what was sensed as probable was the fatality, as in, for instance:

One was injured, and the injury is probably fatal.

But in our judgment-forming we are given to co-thinking some ideas so closely that they take their places in the organism as if they had proposed themselves for membership as one idea. Thus "so injured as to die at once" had, previous to the writing of our illustration formed a unit, and as such was registered by "killed". Analogously, too, "so injured as to die, though not at once" might form a mental unit in the writer's mind, though not expressible by one word only. Accordingly it may be rational to think of "probably" as adverb to the total "fatally injured"; and the opportunities for "parsing" of this order are by no means rare.

III

Some peculiarities of the imperative (by Grammar listed as a mode) have been already noted ("Hybrids") ; but, for present purposes, some further notice is in order. The embarrassment created for us in our youngsterhood by "past imperatives" in Greek suggests a starting point for comment.

The imperative expresses a command to do (or be) — e.g., Go home; (Be still). If what might be commanded has been done already at the time of the commanding, there is no occasion for the use of an imperative; you will not wittingly command me to do what I've done already. Further, even if you do not know that I have done it, you will not command me to have done it or to do it yesterday. You know I am now incapable of any doing in the past; what is commanded will not then be past in time-relation with commanding.

Also doing cannot coincide with the commanding. I can't even know what I'm to do, until you finish telling me. What is commanded cannot then be present in its time-relation with commanding, though a present form with future value may be used: for instance I command that you *be* silent (after my commanding). What is commanded then can only be a doing in the future, reckoned from the time of the commanding.

Whatever then grammarians have imagined, obviously a "past imperative" cannot be past, except in the commanding; this however may of course occur at any time. But my narration that I once upon a time commanded is the merest reminiscence; my announcement that I sometime shall command, the merest forecast—at the most, a threat; whereas my declaration that I do command is actual commanding. The other statements dealt with what had ended or had not begun. In them I merely *talked about* an act; but in the present tense I *act.* To juggle a bit with words, the only time I genuinely command is when I *am* commanding — *now.*

Strictly then the imperative is, in the matter of commanding, present absolutely; in the matter of whatever is commanded, relatively future.

As defined by Grammar, the imperative expresses a command (an exhortation, a request, a supplication), *e.g.*, "Go". This word is obviously a one-word sentence, an announcement which in form is one word only, but which operates with all the power of a sentence — with the power, in this case, of "I command you to go". In this two actions are announced and for each one of them an actor. The question naturally rises: Who in an imperative may be the actors?

Indirectly or directly several individuals may be implicated, namely: the first person, "I", the speaker (even "we"); the one addressed, the second person, "thou", the hearer (or the plural "you"); the third, a "He", an overhearer (or the plural "they") — the person to whose hearing us we don't object, although our thought-communications would not be attempted for his sake alone.[1]

Of all the implicated individuals the "I" alone can be the actor in the imperative act. The statements "You command etc." and "He commands etc." are mere narrations, on a par with "I commanded".

[1] Eaves-droppers and absentees may be neglected.

Of all the implicated individuals my command addresses you alone — for instance, not John Brown; and you must be the doer of what I command — again for instance, not John Brown. I command him "to go" is no command, unless he accepts the statement as addressed to him (accordingly a virtual "you"); and he must do the going. If I were addressing you with the intent that he should go, I probably should say for instance "Make him go" or "Send him away".

In monologue I may command myself, e.g. "Go hang yourself", in which I figuratively trisect myself and, as one part, command myself-as-second-part to hang myself-as-third-part.

To recapitulate, the genuine imperative — the action of commanding — is the present action of an "I"; the doing of what is commanded is the thereto relatively future action of a "you".

Grammarians however stretch the imperative scope, including (as was noted) an imperative past and also a third-personal imperative, for instance "Qu'il vienne", with which at least originally "Je commande" was understood.

They might have done much more: the elements of possible commandings offer great variety; and human ingenuity might even have developed a special word and "mode" for every combination. Thus, to mention in a breath the more conspicuous opportunities I, thou, he , she, we , you, or they command, commanded, will command me, thee, him, her, us, you, or them to do or be this, that or the other — not to dwell on the diminuendo series I command and so forth, request[2] — all which opportunities may serve as merely by their contrast emphasizing the congenital defectiveness of the imperative conjugation.

To apply to adverb-study what we may have learned of the imperative, it is self-evident that the two actions which inhere in the imperative invite, each one of them as verbal, an adverbial adjunct. To illustrate, given

> Now by your children's cradles,
> Now by your fathers' graves,
> Be men to-day Quirites,
> Or be forever slaves,

if "now" be more than merely introductory (as in for instance

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[2] Indeed it is rather disappointing that they haven't made for us a mode of "raise": I cause you to rise is stronger than I order you to rise, and *ipso facto* worthier of modal recognition.

"Now Barabbas was a robber") it should plainly bear on being rather than commanding; so, too, both 'forever" and "to-day".

The command in this case has the attenuated value of an adjuration; and the "by your children's cradles", if construed as figuratively equivalent to "for your children's sake", is more appropriate to being men than to adjuring, and appeals more to Quirites than to their adjurer; so too "by your fathers' graves".

The so-called *dis*junctive *con*junction "or", which introduces a predicting in the figurative guise of a commanding, has the value of "alternatively", as appears in "I command you to be men"; alternatively "I command you to be slaves", the adverb bearing, as it seems to me, rather on the commanding than the being.

To meddle with the function of Quirites will be somewhat like the "buying of a lawsuit". Strictly speaking, as was argued in a previous publication, a vocative is not a part of a speaker's message to his hearer, but the mere address of him for whom the message is intended, comparable to "John Smith — Chicago — Illinois" on an envelope, of which a quasi converse is "Yours truly, Henry Brown".

But in actual practice the "address" appears to me to operate approximately as an adverb, much as if instead of saying "John, I need some help", I substituted "John-wards I declare my need of help". There seems to be some ground then for a ranking of Quirites as a virtual adjunct of commanding in "Be men etc."

The fact that what is commanded by an imperative must be future, reckoned from the time of the commanding, does not hinder more specific time determination; thus a nearer or more distant future is expressed respectively by "Go immediately" or "Go in fifteen minutes".

That other adverbs may apply to what is commanded is a matter of course: Compare Go swiftly, circumspectly, etc.

Also there is room, sufficient and to spare, for adverbs which would register the variant cogency of the imperative announcement, which may range from an authoritative order to a supplication. But the word for ordering or supplicating is suppressed in that extreme abridgment known as an imperative. It would accordingly be over-difficult to recognize an adverb as belonging to a word which has been thus suppressed. Such an adverb — rather the idea expressible by, say, commanding tempered by an adverb — ordinarily at least is left to be suggested by the context, the environment — the "situation", even by the tone of voice etc. Compare

Unhand me, villain.

Give us this day our daily bread.

IV. *Can the verb itself express its own adverbial adjunct?*

Apparently it can. To illustrate, given

He is at home

and

He was at home,

it has been recognized that total verbal values are what might be registered respectively by His being at home is present, or is past.

In French

Il fit chaud

means no mare than merely "It was hot"; but

Il faisait chaud

means "It protractedly was hot" or "It repeatedly was hot" — now one, and now the other.

Probability may be incorporated in the meaning of the verb. Catching sight of an approaching animal, I might say

That's a cow,

which may be true or not. Now, as we all dislike to be caught in a mistake, we are fertile in expedients to avoid it. One of these expedients is to form such a statement that disproving it will be impracticable. If I say that horses in this town are raised on shingle-nails, you can with little difficulty overthrow my proposition. But, if I move this statement to the planet Mars, your task will be impossible; it will be difficult if I put the statement in the distant past; if in the future, again impossible. Horses may not eat nails now; but what do you know about the year 2000?

Suppose now the approaching animal is possibly a calf — a female. Even in English I may hedge by saying

That'll be a cow,

and I am safe; for even if it is just now a calf, in time it's going to be a cow. Accordingly I use the future as a virtual synonym of "possibly (or probably) is".

French goes farther. What is said of the past is difficult to disprove; what is said of the future, impossible. How about a combination of the two?

The so-called French conditional mode[3] historically names what was to be or happen — what was once a going to be.

Ça serait une vache

accordingly means strictly

That was once a going to be a cow,

in which the task of a disproval offers double difficulty.

The violent statement has its force — so also the restrained. The wretch who says to me

You are a fool — a big, a cursed fool

may stir me to resentment. He who says

I think you are a fool

is more humiliating, his expression indicating a superior attitude. The interrogative, as in Are you a fool?, has also on occasion some advantage over the assertive. Thus, in a French novel, rage excited by a wicked woman might have been expressed by

You are a big (or monstrous) devil.

The actual words were

Seriez-vous par hasard une petite méchante?

which, rendered with a full appreciation of historic values still appreciable, might appear as

Were you once perhaps a going to be a little
(wicked person) devil?

or, say,

Am I perchance to understand that you're etc.

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[3] More properly the conclusional mode; for it is used in the conditioned statement, and but very rarely in "conditions".

But translation hardly can reveal the sting of this deliberately moderate interrogation.

The question naturally rises: do ideas of truth (or probability etc.) associate themselves exclusively with the relation element of the judgment?

There has more or less prevailed a notion that it must be we believe in the existence of whatever we may mention. If, for example, you say that Mr. Johnson is your friend, it must be you are certain that there is a Mr. Johnson. Obviously such an inference will usually be correct; for usually we express ourselves about what is, as we suppose, in preference to what isn't — not, however, always.

When I say, for instance, that spiders are not insects, it is true that I "believe in" spiders and in insects; but I do not say so. When I say that ghosts aren't dragons, it is true that I don't "believe in" either; but again I do not tell you so. In neither case does either substantive in my announcement give the slightest hint of my belief or disbelief or any intermediate.

Analogously, in

Her gown is green

the object and the quality are merely postulated. Their relation next is nominated. Next, according as occasion prompts, one aspect of relation is elected — the affirmative or negative (the true or untrue— sometimes intermediate—*e.g.*, probable). Belief in *this* is then announced.

Briefly, we don't bother with untrue or true, improbable or probable gowns or colors.

That other words than verbs can, with no help from other words, express ideas more or less adjunctive to themselves, needs illustration only. "Book*let*", "sour*ish*" do this, though perhaps the syllables italicised should rank as virtual adjunctive words, and merely coalescent with the words to which they are adjunctive. But this topic hardly would repay investigation. Many a concept, too, may be regarded as containing an adjunctive; for example, orange=reddish yellow; scarlet=yellowish red.

V. *On what constituents of an adverb's meaning may another adverb bear?*

This question may be answered with a pair of illustrations: in

A. He very probably took poison,

taking and probability are posed in a relation (similar to the object-to-quality relation that obtains between a noun and its attendant adjective) which might be asserted by

The taking is probable.

With probability an adjunct is in turn associated; the relation that obtains between the two might be asserted by

The probability is great.

That is, in the present case the adverb "very" bears on the attributive (or qualitative) part of what is meant by "probably".

B. He obviously probably took poison.

In this case the "obviously" seems to me intended as a reenforcer of assertion. It presumably is not so much intended that the probability is obvious, as that the relation which obtains between the poison-taking and its probability is obvious, manifest, which in assertive form might be expressed by

(Poison-) taking obviously is probable,

in which the "obviously" doubtless bears on "is", which names the object-to-quality relation of the (poison-) taking to its probability.

When now the probability and this relation are, each one of them, expressed by an adverb bearing on the taking, as in the above exhibited

He obviously probably took poison,

"obviously" should still bear on the "is" contingent — the relation-naming element — of "probably"; and, in

He obviously very probably took poison,

"probably" has two adverbial adjuncts, one for its relation element of meaning — one for its attribute (or quality) element.

VI. *On what constituent of an adjective's meaning does the adverb bear?*

Given

I. She wore a probably green gown,

the adverbial form of "probably" forbids it to associate itself with "She". The order of the words dispels the possibility that "probably" is meant to bear on "wore". An imagining that "probably" might be adverbial to "a" would disappear in "probably green gowns". Not to mention other difficulties, the position of the adverb spoils its chance to bear on "gown". Unless the adverb then be quite irrelevant, it must associate itself with "green".

The title of this section gives a hint that in the meaning of an adjective there sometimes may be found an element not always recognized. The adjective perhaps will be compelled to a confession of this meaning, if subjected to the following torture: given

Her gown is green,

in previous publications I contended that the meaning of the "is" in full may be expressed by "object-to-quality relation plus assertion of its truth"; synonymously, then, "is characterized by" — which is suggested by the natural converse proposition, "Greenness characterizes her gown"; that is, the duty of relation-naming is performed by the so-called copula "is". In other words, the adjective does not perform that duty. It names exclusively a visual equality. But, given

She wore a green gown,

"green" in this case does perform that duty. For no doubt the color is in some relation with the gown, since otherwise it has no right to enter into the recorded sentence; and assuredly no other word than "green" can tell us this relation.

In English the detection of relation is embarrassed by the order of the words — not so in French, in which the adjective would follow its noun: e.g. "une robe verte".

With this in mind it may be easier to see that "a green gown" has all the meaning of "a gown which is green", except the truth-assertion of the "is". That is, in "a green gown" the meaning of the adjective is color, as before, but color plus (and best preceded by) relation, obviously that of object to its quality.

Following the French arrangement of ideas, and completely registering meanings, the illustration reappears in the form

She wore a gown (object-to-quality relation) green,

in which the whole expression in parenthesis is posed as part of what is meant by "green".

In the first considered usage "green", distinguished by grammarians as a predicate adjective, is hardly more to me than a mere synonym of greenness:

(1) gown is characterized by greenness,
(2) gown possesses greenness,
(3) gown has greenness,
(4) gown is green,

are at the bottom different only thus: In (2) and (3) relation has been figuratively conceived, but not in (1) or (4); in the first three this relation is expressed by a verb suggesting action, not however so in (4): in (1) we have imagined that the greenness has "done something" to the gown, and re-imagined (backwards), posing "gown" as suffering the action of the greenness (substituting passive voice for active), which as actor in this action must be substantive; in (2) and (3) we imagine "gown" as "doing something" to its color: otherwise expressed, we pose the color as the object of the verb — again as *ipso facto* substantive. In all these four the color-word expresses color only; differences in the remaining thought are negligible. The adjective, if such it rightly may be called, is in expressive power at its minimum.

But, for example, in "green gown", as argued, the adjective is at its maximum — the adjective par excellence — exhibiting a double symbolizing power; and in the exercise of either power it obviously may be attended by an adverb. This possibility invites us to examine further the initial illustration. Once more then,

I. She wore a probably green gown.

The organization of the judgment thus recorded hardly can be very different, in its latter half, from that which was discovered in

II. Her gown is probably green,

the former being the equivalent of

III. She wore a gown which probably was green,

except for the assertive element — and in this case further a past-time element — which are parts of what is meant by "was".

The argument conducted in the case of II does not require repetition in the case of I. It would lead us to the same conclusion: "probably" bears not on "green" or "gown", but on the object-to-quality relation which subsists between the gown and greenness, this relation being part of what in such a case is meant by "green".

This argument may gain a measure of support if III — a mere extension of I—be juxtaposed with this equivalent though differently organized extension of the same:

IV. The gown which she wore was probably green,

which forces that extension of the "probably" which was in III gratuitous.

It was observed that in

Her gown is green

the meaning of the adjective does not include the object-to-quality relation, which is part of what is meant by "is". In such a case an adverb, if employed with "green", must bear on greenness; for there seems to be no other element of meaning on which it can bear, thus for instance in the phrase "intensely green", of which the asserted equivalent would be "The greenness is intense".

VII. *Will an adjective that names both quality and relation tolerate two adverbs— one for each?*

In answering this question let the situation be reestablished. It is night; the lights are artificial; colors are uncertain; what seems green is possibly blue — and vice versa; the gown is possibly green, and — still more possibly — nearly green. While such a case is likely to be rare,

I. She wore a probably nearly green gown

does not impress me as preposterous; and, though the "probably" might bear on "nearly" or on the unit "nearly green", it seems to me both possible and natural to construe as in

II. She wore a gown which probably was nearly green,

in which the "probably" is made to bear on the object-to-quality relation (which is part of what is meant by "green" in I) while "nearly" bears on the quality expressed by "green" in I and II.

Such developments as

possibly and probably nearly or completely green,

with chains of supplementary adverbs fastening on each of those above,[4] suggest a range of adverbial activity so obvious as not to need our verification.

VIII. *Can a word, regarded by the grammars as an adverb, be the adjunct of a noun?*

My Webster answers "Yes", and cites the expression

Quite a man,

which might however be regarded as a mere abridgment of, for instance, "being fully, quite, a man," with "quite" adverbial to "being" — a construction still more obviously possible in "He is quite a man".

In another, some ways better, illustration "safety first" would be secured by

It isn't true that all that glitters is gold.

But love, perhaps, of the sententious leads to

"All that glitters is not gold."

No doubt the "not" is, in this sentence, adverb to the "is". But the judgment which the sentence (strictly taken) registers was surely unintended: the ostensible subject of this judgment is "All that glitters" — anything, everything, whatever, whatsoever glitters; but assuredly it was not thought that whatsoever glitters is not gold; for plainly some of the things that glitter *are* gold; also some of them are not; and this the author of the sentence probably intended. Having begun, however, with "All", to express himself exactly he should put his negative where it would restrict or curb the excessive scope of "All", as in

Not all that glitters is gold,

in which the "not" which Webster ranks among the adverbs, plainly bears on "all"; indeed there seems to be no other word with which it can associate itself.

It might be claimed that "all" means "all material", analogous to "every thing", in which the adjectival "every" may support

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[4] For instance, "not so very probably, but altogether possibly", etc.

an adverb as its adjunct. But this appears to me gratuitous substitution, unavailable e.g. in

Not John (but his brother) stole the cake.

It was contended in an earlier article ("Linguistic Abberrations") that the function of the "not" in such a case is to reject the following idea, as if I had said

Count out John; contrariwise his brother etc.

While the self-sufficiency of an imperative construction readily shrinks to the dependence of an adjunct, still the adjunct must maintain the bearing of the original imperative: "Not" must bear on "John".

IX. *Can a word, regarded by the grammars as an adverb, be the adjunct of a preposition?*

As, for instance, in

The thief jumped surely over, not through, the hedge.

(1) If this announcement were the outcome of my observation that the footprints on the further side were deeper, and if this suggested jumping rather than for instance straddling, I should say of the thief

He surely jumped, not straddled.

(2) Possibly however I observe no more than that, although the footprints register a passage from the nearer to the further side, the hedge remains uninjured. Between the thinkable overness and throughness of the passage I decide in favor of the overness. I might then say The overness is sure; the throughness inadmissible. The first I seem to mean in saying "surely over"; the last is rendered by "not through" (in which the "not", as argued on p. 11, is adjunct of the following word).

As a factor in expressing the intention presupposed in (2) the "surely" (which its ending advertises as an adverb) cannot bear on "jumped"; and with the object of "over" not yet in mind, and forced to wait for (and be disconcerted by) "not through", it hardly can be possible for "surely" to be sensed as bearing on the whole adverbial expression "over the hedge" — hardly possible in my thinking — much less possible in my hearer's thinking. The situation differs far too much from that presented by "jumped surely over the hedge — not through it".

Accordingly my answer to the initial question would be Yes.

X. *Can an adverb be the adjunct of a conjunction?*

As, for instance, in

"The greatest of all modern and perhaps ancient poets".

Imprimis there's no verb for the presumably always adverbial "perhaps" to serve adjunctively. A verb indeed is readily suggested for the adverb by the quoted sentence and might be expressed, for example, in

(poets who are modern) and poets who perhaps are ancient.

But the "perhaps" declines to bear, it seems to me, on "are". The writer of the sentence hardly meant that possibly some poets should be ranked as ancient. The suggested verb does not appear to "mend the jape".

The writer also hardly meant (with but a trifling difference) that some of the poets should be ranked as possibly ancient. There appears accordingly to be no adjective to which "perhaps" might serve as adjunct.

Obviously too there is no other adverb on which the "perhaps" might bear.

Grammar's possibilities, for an adverbial service, seem accordingly to be exhausted. Yet "perhaps" must bear on *some* word or remain a stranger to the sentence.

If we drop our grammars and rely on what we think we know we mean, the difficulty may be solved. Putting ourselves in the writer's place, we recognize that our uncertainty (expressed by the "perhaps") is whether we should confine ourselves to modern poets or may include with them the ancient. It's the adding — the association, grouping, of the ancient with the modern — that's "perhaps"; and this would be expressible, for example, by

modern, possibly also ancient poets,

in which for me the "possibly" would bear on "also"; and for me "perhaps" analogously is the adjunct of the "and": the adverb "limits" a "conjunction".

Although I cannot recognize that "but" in the following illustration is a conjunction[5] let it serve for what it may be worth:

All men but if you will, the illiterate, should vote,

in which the "but" is limited by an adverbial clause.

Analogously, in

Those fools or — if you don't like that, those scoundrels — should be punished,

the condition seems to bear upon the "or" — upon the offering of an alternative, rather than upon the alternative offered, i.e., "scoundrels". That such is the correct interpretation of the sentence as it ordinarily would be used, may be denied. But you will probably concede that one *might* so intend it, which is all it needs as illustration of a possibility.

XI

Grammar recognizes that an adverb may be adjunct of a verb or adjective or other adverb.

Webster adds the noun, e.g., in "Quite a man"; and, corollary-wise, presumably the pronoun would be further added, e.g., in "He wasn't quite himself"; for the contracted "wasn't" indicates that "was" has exercised on "not" the right of eminent domain.

The article — a merely weakened adjective — may be expected to enjoy the latter's privileges, leastwise when uncommonly important, e.g., in "The Siamese twins were two men — hardly one man — hardly *a* man", in which "hardly" *can* be meant to bear on "a" directly — not on "was" implied or understood. In like vein "He is certainly *the* man of the hour."

The participle (verbal adjective), an intermediate between the verb and adjective, may be expected to maintain the common privilege of its two prototypes — e.g., in "carefully aiming his pistol, he fired."

Instances have been examined in which adverbs have appeared to bear on prepositions and conjunctions.

The interjection (of which interloper, as suggested elsewhere, is almost a synonym), as it is strictly not a sentence-element, can hardly rank among the parts of speech.

Has any one of them been overlooked?

Or is there any "part of speech" to which a word regarded

[5] Rather a preposition or an imperative according to the user's state of mind.

by the "grammar-book" or dictionary as an adverb may not serve as adjunct, i.e. "limit" it?

PART II. THE PREPOSITION

The field, of which the exploration is suggested by the above title, may be narrowed somewhat by elimination of some

Pseudoprepositions

To illustrate, "on" in

"On! Stanley, on!"

is obviously equivalent to "onward", which presumably is adverb to a verb omitted but implied, for instance "ride" or "rush" or "hasten", as presumably the adverb also in

"Forward, the light brigade!"

In other cases an ostensible preposition's object is included in its meaning; and the whole becomes an adjective or adverb: thus, for example,

Is Mr. Johnson in?

in which the "in" suggests as much as "in the house" — analogously, "out" in

No, Sir; he is out.

In this connection it may be observed that in the meaning of the adverb commonly a prepositional element may be detected, as e.g. in "here" (*in* a place that's near to me, or both of us) or "there" (*in* one that may be quite as near to you, but not to me) or "yonder" (*in* one somewhat far from both of us). Such inclusion of a prepositional idea obviously no more makes a preposition of the adverb than the "onward" resident in "charge" makes of that verb an adverb in, for instance,

"Charge, Chester, charge."

Analogously "fluently" is not a preposition, though definable by "*in* a fluent manner."

Again, among the many efforts to find for "than" a place among the parts of speech, it has been rated as a preposition. But German with its "als", and French with its equivalent "que" — the Latin "quam" — are etymologically hostile to this rating; and the mere citation of the usual "older than I" — or would the prepositionists prefer "than *me*" — might seem to answer them sufficiently.

But to continue, in the history of speech the chances are that longer words are not evolved from shorter. Also, as a rule, in phraseology the earlier, like a stream in arid regions, starts with all its volume, but decreases in descending from its source. Accordingly the expression

Older than you

may be assumed to have descended from the earlier, but still employed

Older than you are (old or "le" for âgé in the French),

in short, to have suffered an ellipsis; he accordingly who poses "than" as prepositional in the simple "older than you", must mend his methods when he reaches e.g.

I was older than you are now
I was old—exceeding what you are now
I was old—exceeding that which you are now
I was old—exceeding the degree to which you now are old

Unrecognized prepositions.

On the other hand some prepositions have been rated as conjunctions, e.g.

"*Though* He slay me yet will I trust in Him,"

or, leaving out the unneeded "yet", and modernizing,

Though He slay me I will trust Him.

Thus presented, slaying and trusting plainly are exhibited by "though" in a relation of antagonism — a relation somewhat difficult to name with more exactness, as a suitable expression for it has apparently not, thus far, been developed. If, instead of "Though" we had "Because", or "Since", we should unhesitatingly declare relation to be that of cause-to-effect. But slaying hardly is conceivable as cause of trusting; it is quite the contrary. Causative power in general no doubt it has; but in the present case that power is ineffective — cannot overcome the force of other causative energy, which however is left to be imagined. Trusting poses then as an effect, but not of slaying, which antagonizes it. The opposite of cause is followed by unexpected effect — a fact which readily suggests, as name for the relation, counter-cause to effect (of other causes).

"Because" and "Though" accordingly appear to rank alike, and may lay claim to rank like the French "quoique" and the German "trotz" (in spite of) with the prepositions.

Analogously "if", as indicated by the prepositional equivalent phrase "in case that" (Webster), seems to me to function as a preposition, though at first sight on a par with "when". To illustrate: given

If the shower ceases I shall take a walk,

and

When the shower ceases I shall take a walk,

it's plain that "If" etc. means in a particular case, and "When" etc. means at a particular time: the two adverbial clauses are constructed on a single plan. But that they are not so much alike in purpose as at first they seem, is indicated by the fact that "If the shower doesn't cease" is quite a tenable hypothesis, which promptly offers an entirely acceptable sequel in "I shall not take a walk". But "When the shower doesn't cease" not only doesn't cordially invite my further cerebration, but it also seems to lie entirely beyond my thought-horizon. I was using "When the shower ceases" to precisely fix a date; and that I cannot fix by that which doesn't happen; a not-happening may be at almost any date.

To look accordingly a little closer, it is plain that "when", though one word only, may be sensed as representing several ideas. These appear distinctly—with the total sentence more conveniently arranged — as follows.

I shall take a walk at the time at which the shower ceases.

In this expression it is plain that "when" has not the value of a preposition, but of a doubly prepositional phrase (expressing time in double factorship) — or, so to speak, is not a preposition, but contains a pair of prepositions — is no more a preposition than for instance "then", which may resolve itself no more absurdly into "at that moment".

Now there seems to be no need and hardly opportunity for such extension of the "if". This word indeed may be expanded into "in the case in which" — a phrase which plainly parallels in form our "at the time in which".[6] The two expressions are however very different in substance. The time at which the shower ceases posed the date of walking as the date determined by a ceasing; and the ceasing as a date-determiner was valid only so far as that ceasing could be trusted to occur. In other words the ceasing was with "when" assumed as certain to occur at some time not presumably remote.

Per contra ceasing is, with "in the case in which", exhibited as (during time considered) totally uncertain; "case" in this connection means what merely is conceived, imagined.

In a nutshell then, with "when......., etc." I wish to help you fix the time at which I walk; with "if......., etc." I wish to help you determine whether I walk at all.

The two expressions operate alike adverbially — bear upon the walking; but in different ways; the "when" clause bears upon the act of walking; but the "if" clause bears on the reality or truth of walking — or rather on the scope of truth, to which it sets as boundary the realizing of the "if" hypothesis.

What concerns us here is the relation of the realized hypothesis to the by it restricted truth. To aid perception, let us set beside the hypothetical cessation of the shower the correlatively hypothetical noncessation of the shower; and for the moment think of them as realized, first one and then the other; also put them in the past, to thus eliminate the opportunity for speculation as to what may happen in the future.

Say the shower didn't cease — that it continued. It is rational enough to put it that continuing prevented walking — that continuation operated as a cause preventively, or as a "counter-cause". At least we should presumably regard relation of continuing and walking as belonging somehow in the causal group.

Per contra say the shower ceased. Cessation — that is, the removal of preventive cause — can hardly pose as being of itself a cause of any sort — a cause of anything. The shower after a fashion made me stay indoors; but its cessation didn't make me walk; it wasn't causative; it certainly was not preventive; it was, say, permissive, leaving me unhampered, to do as I pleased.

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[6] But "case in which" is much more possible than plausible, impressing me as an instructive, garrulous advance-agent of "the shower ceases".

The relation thus established, registered by "if", is usually known as the relation of condition to conclusion, though it would be clearer to dismiss "conclusion", substituting "what is conditioned"; for the natural arrangement of my illustration would be as in

I shall take a walk if the shower ceases,

which is a conditioned statement; and the statement is, in organizing thought, more dominant of course than what (adjunctively, adverbially) conditions it. *Per contra* the accepted phrase "condition, and conclusion" tends to falsely pose the two on equal terms.

Now what is known as a condition, being a hypothesis — imagined only — may be introduced, for instance, by "figurez-vous" (picture to yourself, imagine); by "say"; by "let, as in "let A B C be a triangle"; by "suppose"; by "grant"; or negatively by "except" (and the participial "excepting" and "excepted") — also "save".

All these indeed are verbs in the imperative; and yet "except" and "save" have long been ranked as prepositions; for a little dimming of appreciation leaves the verb in excellent condition for the strictly prepositional function. "All except yourself" is easily construed as "all without yourself"; and "all but you" at first meant literally "all except you". The earlier English "an" in the sense of "if" was an Anglo-saxon imperative; so too, as some would have it, was our "if" itself, once written "gif".

But, whatsoever may have been the meaning and the function of the "if", there seems to be but little room for doubt that now it functions as a preposition, governing a following quasi-sentence treated as a substantive — its object.[7]

It is interesting to observe that "if" and "though" alike at first meant "grant", "admit", "suppose". To-day the latter means (with few regrettable exceptions — thus "as though" instead of "as if") "suppose as an obstruction"; while the former means "suppose as a permission or remover of obstruction". Analogously "weil" in German means "because"; but "while" in English means "although".

[7] The verb of the "if" clause obviously is unassertive, only in form indicative, in meaning a subjunctive, *ergo* fit to serve as a verbal noun.

Note the practicability of

If the shower ceases I shall take a walk when it ceases,
In the case of ceasing I shall take a walk at the time of ceasing,

which exhibits neither two conditions, nor two dates, but one of each.

"If" does all the business of the prepositional phrase "in case of", which in sentence-building functions as a preposition; "if" accordingly has equal claim to prepositional rank.

Note that "if" expresses the relation which obtains between the walking and the ceasing; "when" expresses the relation which obtains between the walking and a date determined by the ceasing. The two respectively are answers to the questions "Shall you walk?" and "When shall you walk?"

The Name and Definitions of the Preposition

The reason why this "part of speech" is called a preposition has been said to be that it is put before its noun—a symptom far from diagnostic; adjectives are commonly put before their nouns; and verbs before their objects.

Those who named the preposition are not much excelled by those who have defined it as a word that "names a mere (!) relation"; for so also does the verb, and much more notably; and so may, strictly speaking, other parts of speech; for instance, the noun superiority, that is, the relation of superior to inferior. What other word will merely *name* what is intended by the algebraic symbol $>$? Its partial synonym "exceeds" is obviously assertive.

The futility of the current name and definitions of this "part of speech" suggests some care in its examination, which may be both stimulated and assisted by considering the next topic.

Age of the Preposition

It is very old, as indicated by the fact that legionary meanings are expressed by a little group of prepositions. Goold-Brown's list, when reasonably pruned, contains a score or so. Some old ones have been lost; and few, if any, new ones have in recent times been coined. Obviously many of them must do double, multiple duty. Webster offers eighteen titles for the meanings, or the meaning-groups, expressed by "of"; and the list of them is far from complete. A single illustration may suggest their range of difference. In "the murdering of Lincoln" "of" exhibits the relation of action to actee or object. In "the crime" or, more specifically, in "the Lincoln-murdering of Booth", relation obviously is that of action to actor. It is hardly probable that any preposition started its career with a so large and varied burden. Meaning has presumably been piled on meaning at the outset scanty. Such accumulation (making "of" suggest a universal preposition) slowly forming — till of late the journalist almost would have all the prepositions interchangeable —requires time, and time somewhat as the geologist conceives it.

Many verbs, to express their meaning, join to themselves a preposition. Their number is extremely large; and each of them is witness to a prepositional antiquity.

That prepositions must be very old is further indicated by the long advance that many of them obviously have made in what, for lack of a better word, may be called their intellectuality. As warrant for this word, it may be noted that a single preposition may express relations of time, of space, of cause-and-effect. Of these it is plain that difficult relations, e.g. those of cause and effect, imply a higher grade of cerebration than the easier, for instance those of mere location or direction. Also, in the evolution of the mental powers, it may be assumed that lower grades of cerebration had been practiced long before the mind was ready to attempt the higher.

To illustrate, in

from the house[8]

the space relation named by "from" impresses me as well within the mental scope, for instance, of a dog.

"From early morn (till dewy eve)"

presumably would call for higher cerebration.

To rise now in the intellectual scale,

I have a cold from a chill (or being chilled),

in which the "from" may be interpreted as showing "cold" in the effect-to-cause relation with "a chill".

The progress from the spatial to the casual, even viewed as

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[8] As in, "The barn is (4 rods) from the house".

progress in communication only, is remarkable, and hardly could have been accomplished otherwise than step by step. At every step moreover the expedient of rather vague suggesting doubtless was employed long before attainment of what strictly could be called expressing; it is safe to say that in linguistic evolution this suggesting is the much frequented bridge to telling.

To illustrate, digging down a bit, we realize that in our thinking of location or direction we require a preliminary basal point in space, a point from which we reckon — say an "origin of coordinates", which for our purposes we may more simply call a "here". The preposition "at" suggests relation that obtains in space between our "here" and a nearby "there"; while "from" suggests relation that obtains between a "here" and a remoter "there" in space. When now (for lack of a word to name the similar relation that obtains in time between for instance 'then" and "now") the "from" presumably was forced to serve with time, it gave an adequate hint of the relation later named by "since" (in time) and gradually took on that relation as a meaning which in suitable environment it actually expresses. Further, given "from" in its new sense of "since" (in time), when it was further forced to serve with cause and its effect, it once more hinted at the requisite relation, and in time adopted it as one of its actual meanings, finding with notorious ease the path from "post" to "propter hoc".[9]

As said before, the advance in power of expression is remarkable; but our advance in thinking power seems to me enormous — its accomplishment astounding. Here we are; but how did we get here? All ideas known as abstract are comparatively difficult — whiteness more than snow, sequence more than this-succeeding-that in space and even time. causation more than "chill" and the ensuing "cold". The difficulty of the last abstraction is extreme — inevitably so.

As relation is the mind's reaction to the stimulus exerted by a pair of terms, it might be claimed that, somewhat as without an eye there would not be what we call color, so without a mind there would not be relations; that, e.g., were mind eliminated, while the tree-top and its roots would each maintain its place,

[9] To me the rating of a "since" (thus used) as any part of speech except a preposition—e.g, a conjunction, adverb (?)—ranks of course as merely trifling.

the former would no longer be above the latter. The relations seem to me a purely mental product utterly remote from whatsoever be *in rerum natura—not "of the earth, earthy"*. *To* think them separate from their stimuli accordingly may be regarded as the great and fundamental difficulty in our thinking for linguistic purposes.

Thus, however, they must be thought. A single illustration is perhaps sufficient: if you say "excess", I think at once of its relation indicated by the algebraic $>$. To do no groping into subtleties, it is enough to note that this relation didn't travel through the atmosphere from you to me astride of the word "excess"; you merely summoned an idea to my mental foreground; to be summoned thus, it had to be in waiting in my mental background — better in my mental store-house of ideas. I admit that by description, information, you can build a new idea in my mind; but that is educating me — not ordinary telling me. With such exceptions, what you say can do no more than call up my already formed ideas; it is most emphatically not a "vehicle".

I see no reason for supposing this relation to excess, while waiting in the back-ground, to have been accompanied by stimulating terms, for instance Moon and the much smaller looking Jupiter. Their room is better than their company. In speaking to me, you intend that duplicates of your ideas shall occupy my mental stage. Now this was not constructed on a three-ring-circus plan: one show at a time is all it can accommodate with full success. If I am to grasp your meaning when you say "Demand exceeds ——— ", I mustn't be thinking of the moon and Jupiter. Even if they have been hitherto required to help me to maintain in mental storage the excess relation, obviously they have left me now, "Demand" has ousted "moon"; and "Jupiter", unable to put up with the inglorious fellow-term "Demand", has doubtless fled the scene. As I don't know the economic laws, I can't anticipate "supply". I'm left with a lonesome "Demand", which cannot single-handed stimulate the "excess" relation: "exceeds" must do that business.

It appears accordingly that there are leastwise momentary situations in which a relation must be thought without the help of terms. With adequate investigation we should probably say as much as this: in first experiencing a relation we required two terms as a stimulus; but what they stimulated has become, without its terms, a permanent addition to our repertory of ideas.

To resume, the prepositions, which today express ideas most elusive, started with ideas quite obtrusive — the objective space-relations. Reaching so far back in time, the history of the prepositions makes a notable approach to being the history of mental evolution.

To compare the preposition's age with that of other parts of speech we must look back, or rather think back, far indeed. We can not be "echt wissenschaftlich", as conceived and commonly demanded by philologists. But speculation, although much derided, has achieved results both plausible and helpful.

It begins, far back of what can be regarded as a judgment, with a (mental) recognition of perhaps at first a mere sensation, or distress, for instance, thirst. The infant, stimulated thus, at first makes no more near approach to speech than to emit a purely reflex cry. The cry however brings relief. The repetition of this sequence leads to the cry intentional and purposeful: language has begun.

From distress it is not far to the desire of relief; and from relief the path is straight and short to that which has so often brought relief.

Given frequent repetition of e.g. "Does Baby want a drink of water?", naturally "water", as the final and most emphatic word, distinguished further by its higher pitch, should form an adequate association with the infant's mental status; and the cry should be replaced by a near-utterance of "water", which presumably the infant would at first intend to stand for all that was in mind; and, even if a single element of mental status were intended, it should be remembered that at first no doubt the baby knows much better that he wants than what he wants — "water" might be uttered in the sense of "want". But "water" would no doubt soon reach its proper meaning.

Some day, doubtless very early in the mental evolution, comes the first (?) dichotomy, the recognition of the all-that-is as made up of a self and the remainder; this would naturally lead to "Baby — water". Further recognition of the mental status in its details would develop "Baby-want-water", which however is to me still far remote from the sentential judgmentregistration "Baby wants water". What the baby utters is a list of names for ideas — nothing more.[10]

To illustrate this distinction,

"On the Grampian hills my father feeds his flocks",

of which, I am informed, A Pidgin-English version reads as follows:

"*Top* side Glampian-*hill* me *fadder chow-chow* him *sheep*."

of which the words italicized alone require attention.

Though knowing nothing of whatever syntax Pidgin-English may possess, I see no need in it of differentiated "parts of speech"; for all the words italicized, if parts of speech at all, to me are nouns, including "chow-chow", which was introduced to me as naming a kind of pickle, and is to me no more than special "food" or "fodder"; and, though "top" successfully takes the place of the relation-naming "on", I rank it as a make-shift — not an equivalent: "top" and "bottom" seem no more to indicate (perception of) relation than for instance "head" and "foot", or say the big end and the little end — the hot end and the cold end — of the tapering stick that I pull out of my fire.

But such a "top", or "top-side" is at least a prepositional germ, and obviously could acquire a genuine prepositional meaning. Furthermore, the germinal judgment seems to be that registered by

Father - food - sheep ------ on ---- hill,

in which the "on" requires recognition thoroughly distinct, before the details of the group preceding it. We may presumably with saftey say the preposition is at least as old as any of the sentence-elements, except the noun.

The preposition shows its nature most distinctly when compared with other parts of speech;—as most convenient, in the first place then a brief

Comparison with other parts of speech not verbal.

To illustrate: in

The book *on* the table has a very excellent reputation

it is obvious that the preposition's function is completely and

[10] Even the word order is perhaps no more than initiative; any other order hardly need surprise us.

extremely different from that of "book", the first term, subject-noun; from that of the last term "reputation", object-noun of the verb; from that of the preposition's object-noun the "table". It also plainly differs absolutely in its function from the adjunct (adjective) "excellent", the "articles" or weakened adjectives "the" and "a", and the secondary adjunct "very" ranked by Grammar as an adverb.

There is also in a preposition little — rather, nothing — to remind one of a pronoun, which is merely a noun with a peculiar meaning or peculiar mode of meaning — exhibition, e.g., by the reinstatement of a meaning previously offered by a noun, as in "That *wagon* has been roughly handled. *It* is badly damaged." See "Pronouns" in an earlier paper.

With conjunctions — "words which join," as defined by grammars — a comparison would be embarrassing, until they have been carefully examined — see the closing chapter of this publication. Meantime they will hardly be confused with prepositional namers of relations.

As for the interjection, which has been defined as a word "thrown in between words connected in construction" — i.e. in the sentence but not of it — being a speech-interruption, it can hardly rank as a "*part* of speech".

Hybrid Preposition

Though the preposition in its thus far noted function as preposition only, plainly differs greatly, for example, from the noun, the question rises whether it can doubly operate as preposition and, e.g., as noun — that is, in one of its functions *be* a noun.

It theortically can. The preposition, it is true, as naming the relation which obtains *between* two terms, dislikes to stand before or after them, and *ipso facto* isn't in a good position to do service with what follows or precedes them. But if this dislike be overcome — if, taking as our model

"Under a spreading chesnut-tree
The village smithy stands,"

we meddle with it thus —

The smithy stands a tree beneath,

we can continue (juggle) as suggested by this diagram:

(The smithy stands a tree [beneath) is not the word the author chose]

in which "beneath" is preposition with "a tree" (its object), but is noun as subject of "is not" etc.

As merely one more curiosity, it may be noted that "beneath" though thought but once, is indispensable to both the judgments (bounded, one of them, by parenthetic marks, the other by the brackets). It accordingly connects or "joins them, and might file a claim to rank not only as a preposition, but as also a conjunction, though this claim presumably would be disputed by grammarians.

Comparison with Verbs

The Germans call the verb the time-word; but this name applies as well, e.g. to "hour", "noon" and "yesterday", which in expressing time, do better work than verbs do in their vaguer indication of the present, past and future.

Our grammarians have defined it as "denoting action, being or state," which words accordingly should strictly, all of them, be ranked as verbs themselves; so too, e.g., "gymnastics" or "existence" or "unconsciousness". Such definitions do not greatly help.

Perhaps we shall have better luck if we resume examination of the judgment part of which a verb is needed to express.

In every judgment there must be at least three elements, or say ideas, namely two and the relation[11] that obtains between them. To illustrate, if I merely think of oranges, I have not formed a judgment. Even if I think of oranges, and further think of lemons, I have done but little better. But if I think as registered by "Oranges exceed lemons", I have formed a judgment. I have thought not only of two terms, but also of a relation expressed by "exceeds" — a relation which obtains between the two.

I have indeed done more than this — a very important more. I have added an idea of, roughly speaking, truth — as is apparent on contrasting "Oranges exceed lemons" with "Oranges

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[11] A relation may be said to be the mind's reaction to the verbal presence of two terms—the most important element accordingly in judgment-forming.

don't exceed lemons". I have further added, roughly speaking again, my own belief in this truth, as is apparent on comparing "Oranges exceed lemons" with "Oranges to exceed lemons".

But unfortunately "to exceed" is also generally called a verb. Verbal it is indeed in its relation-naming power; but in comparison with "exceeds" it has both lost and gained: assertive power it has lost; but it has gained the power to function as a noun; e.g. in

Brown declares oranges to exceed lemons

"to exceed" is at the same time unassertive namer of relation — that between the oranges and lemons — and the direct object of "declares"[12] — in other words it is a hybrid — known as a verbal noun, to be examined later.

It favors clearness, both of thinking and of telling, to regard as genuine those verbs only which express (the speaker's) belief in the relations which they name — that is, the assertive verbal forms; to rank the unassertive forms as verbal nouns, verbal adjectives or verbal adverbs — that is hybrids; see p. 18. This policy admits to genuine verbal rank the Indicative mode alone; for though (as previously indicated) the Imperative does assert, what it asserts is a command or wish that has been added to the meaning of the verb, developing thereby what might be with advantage rated as a different verb; so too the interrogative verb, as in e.g. "Is that your hat?"; for, though it also does assert, what it asserts is a desire that the hearer give particular information. See "Interrogatives".

This genuine verb — defined above — alone expresses that relation which is dominant among the many that may play a part in the construction of a single judgment. Thus, in

The book on the table is mine

the dominant or primary relation (that of substance to attribute or accident — a trifle figurative) is expressed by "is", while the positional relation of the book and table, registered by "on",

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[12] That it is more true to actual thinking to construe the sentence thus, than to regard the total "oranges to exceed lemons" as a unit object of "declares", is indicated when, e.g., you pass from "I saw Booth murder Lincoln" to the more compact—and much more unity-suggesting—"I saw Booth's murder of Lincoln", in which, however, "murder" would presumably be ranked by a grammarian as the object of "saw", before he came to reckon with its adjuncts "Booth's" and "of Lincoln".

is obviously secondary in importance; for, even if the relation named by "on" (and also its following term) be omitted, what remains is still a judgment, true or untrue; but, without the "is", the remainder has no longer any judgment value, save as "is" be understood with it.

As already indicated the preposition is not assertive. If it were invested with assertive power, it would obviously rank as a verb. For instance given

Your book is on the table

if I could say of the book

It ons the table,

using "ons" as synonym of "is on", plainly "on" would be essentially equivalent, e.g., to "overlie", asserting the spatial relation of the books and table, and accordingly a genuine verb.

Verbs expressing Prepositional relations

(a) *Verbs compounded with a preposition.* The list of verbs which thus express relations also registered by prepositions is exceedingly large; for instance, "invade", which roughly duplicates the meaning of "go in" (or into). But the syntax of the former isn't prepositional; for, as part of the verb, the preposition operates as in "go-in the house"; while, in the latter, as a separate word, it operates as in "go in-the-house". Compare for instance "What are you invading? or entering? The house." and "Where are you going? In the house." Of such distinctions more hereafter.

Another difference between the verbal and the prepositional exposition of relations may deserve attention. Verbs preponderatingly treat of action. Not to repeat protracted argument, it is rather obvious that action may be postulated as an output of energy; this can hardly be detected save in change; and change implies establishment of new relations. Thus for instance in the case of Newton's falling apple, its original relation with a tree gives way to a relation with the earth.

Accordingly the active verb may properly be said to treat of action-formed relations; and in this connection it is worth observing that the preposition varies now and then to suit the verbal meaning. Thus "to-be" is followed by the preposition "in", for instance

He is in the house;

but "go" is leastwise often followed by the preposition "into", as for instance in

He went into the house.

Analogously German views the prepositions *über, in* and *unter* as requiring the dative when employed with a verb expressing status — the accusative with verbs of motion.

Unfortunately in linguistic dealing with such matters we are governed by the well-nigh universal fallacy that things can *"do* things". Heedlessly we say the apple struck the earth. We even plainly tell ourselves the apple did the striking, and our planet suffered the blow. Still further we are faithful to our fallacy, even when there's not the faintest trace of action, as for instance in the utterly inactive status specified by "A and B are equal". For, when once we substitute "A equals B", we call our B the direct object or accusative, and down goes "equals" in the dictionary as a transitive, requiring an actor for its action, much as if a violent A inflicted the equality on B.[13]

We think we know that verbal meaning by its nature preestablishes the indirectness or directness of its object, though we do occasionally suffer a rude shock.[14] While we for instance speak as if "to like" or "love" could be relied on to affect a beefsteak or a woman, we discover that the Spanish better grasp the situation, using the expression "to love *to* (or at or toward) a woman."

In such embarrassment my own expedient and relief has been to sense the active verb as registering both an action and a thereby formed relation — all together, a relation-forming action (or activity). E.g. a dinner is given — say a dining occurs; as one of the viands chicken is served; the guests eat chicken; the act of eating develops between the guests and chicken the relation of eater-to-food, or diner-to-dinner; "eat" exhibits a relation in its forming or becoming.

Such an exhibition of relation in its "werden" versus "sein" is not, so far as I recall, effected by a preposition.

(b) *Uncompounded verbs.* Examining with some care rela-

[13] Webster 1867, "a verb expressing an action which passes...... from the subject which does to the object on which it is done."

[14] For instance, from "utor" etc.

tion-words presented in Roget's Thesaurus (old edition alone at hand), I notice that apparently the only verbs of which no preposition forms a part, but which in spite of this express a prepositional relation, are "to face"[15] and, more distinctly, "flank", as in

His house flanks my house,

which is obviously equivalent to

His house is beside my house.

But, even in this case, again the verbal and the prepositional proposition differ greatly in idea-organizing. In the former the idea of lateral proximity is part and parcel of the verbal connotation. In the latter this idea deserts the verb and forms with subsequent ideas a virtual attribute, as indicated by this punctuation of "beside-my-house". The two procedures may be thus exhibited:

I.	His house	flanks	my house
II.	His house	is	beside my house

In I the mid-term falsely sensed as naming action, is attended by a would-be actor (subject) and an actee (object) and declares a quite imaginary actor-to-actee relation of his house and mine.

In II the mid-term "is" presents the substance-attribute relation and declares that it obtains between the two terms "His house" and "beside my house".

This departure from the current doctrine of the "copula" upheld by grammar was laboriously defended in an earlier publication. At this point it may be enough to juxtapose e.g.

I. My house is white

and the converse proposition. But, says high authority, Germanic and accepted by the multitude, it can't be done; for every judgment predicates an attribute of substance. Of this dictum let a single aspect be examined: the implied command to start with substance in forming a qualitative judgment.

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[15] The space relation designated by this word, although of prepositional character, is not apparently expressed by an unaided English preposition, but by equivalent phrases such as "opposite to", "in front of", "over against", with which compare the German "gegenüber".

Suppose we *want* to start with attribute. I think we *can*, as in for instance

II. Whiteness characterizes my house.

Forestalling odious interpretations of this sentence, I declare that I do not senselessly or figuratively conceive of whiteness as a "thing" which in this transitive-looking sentence "does things" to my house. I merely mean that whiteness and my house are in the attribute-to-substance relation; and, my observation being thus a little sharpened, when I now pass from this sentence to *its* converse, the original "My house is white", I seem to see with even greater certainty that what I meant by "is" — the so-called "copula" — was what may be expressed by "is characterized by"; in other words the "is" asserts relation of substance to attribute; my I is, so to speak, the passive form of II,

That "is" in other cases registers relations altogether different, was argued in preceding publications thus, "(All) men are bipeds," in which the relation is of a species-to-genus type, the genuine converse being the genus-to-species type expressed by "Bipeds include (all) men." Accordingly "All men are bipeds" means "All men are included in bipeds", which does not suggest the stipulation of "*some* bipeds," an invention, as it seems to me, of which the "ninety and nine" know nothing. Again, in "Brown is eating" the relation is that variant of substance-to-attribute which may be known as substance-to-accident" or incidental attribute, of which the converse, were it needed, might be rendered by, for instance, "Eating just now characterizes Brown."

In this connection we do well to keep our mental back-door shut against the idle notion that, because "His house" is substance, and "beside my house" is attribute, this attribute is therefore attribute of that particular substance — that the two are in the substance-attribute relation. Mention of them in a single breath suggests it; but it isn't certified until declared by "is". "In the river" also is equipped to serve as attribute, but not of either house until there comes a flood.

The usual functions of the prepositional phrase in judgment-organizing are most obvious; e.g., in

Oranges of full growth

the last three words restrict the scope of "oranges" precisely as "full-grown" in

Full-grown oranges;

that is, they are adjunctive to a noun — say adjective.

On the contrary, in

It is well to eat an orange in the morning,

the adjunctive prepositional phrase is obviously adverbial.

When it is remembered that each judgment-element that may be added to a minimal judgment, e.g., "Men are animals", must be in some relation with an already admitted element, it is obvious that the number of relations that may play a part in judgment-organizing must be very great; and their respective ranks in the organic total, whether expressed by prepositions or by other words, may be worth an illustration. Thus in

Brown declares with emphasis the apparent
book on the table to be in fact a candy box,

the dominant relation is of course the one asserted by "declares" as holding between Brown and what he declares, of which the skeleton is "the book — to be — a box." This skeleton exhibits "to be" as naming a relation secondary to the dominant relation manifested by "declares". The prepositional relations plainly are remoter still from dominance; but their respective rating lends itself to argument. Thinking first of the degree to which each one is useful in avoiding a misunderstanding, one would naturally give the first rank to the "on" and follow with the "in" and "with". But, thinking rather of their rank in syntax, one might well assign the first place to the "with" as operating with the dominating verb — the second probably to "in" as operating with "to be" (the heart of what is declared) — the third, to "on". Enough that, from each point of view, the dominant relation may be attended by other relations differing in importance or prestige.

Comparison with Hybrids

The difference between the verb and preposition is maintained by verbal hybrids, of which, in our actual use, a larger possible number (see "Hybrids", pp. 151, 195, and 202) is reduced to three, the verbal noun, the verbal adjective, the verbal adverb — this extremely rare, e.g., She sang ear-splittingly.

Analogously,

Henry shouted me-addressingly

is thinkable; and even

Henry shouted to-me speakingly,

This last is organized precisely on the plan of

Henry shouted speaking to me,

save only that the adjunct in the one case bears upon the verb, and in the other on its subject. Nothing then is likely to be gained by special study of the verbal adverb.

On the other hand, in

Henry's speaking to me was a shouting,

"speaking" is no longer an adjunctive, but the subject of the sentence, differing from

His addressing me was a shouting

only in conceiving "me" as direct object versus indirect. Obviously this verbal hybrid, recognized immediately in its leading function as a noun and subject of the sentence, can't have much in common with a preposition functioning between two terms as their relation-namer. It's the verbal adjective — the "participle", if the word be used synonymously — that invites comparison with prepositions.

This comparison may be aided by a brief examination of the several relations which the verb (in the active voice) on different occasions is required to express. For instance, in

The jockey rides (three times a day),

the first term "jockey" must be in relation with some other sentence element; and none is visible save "rides". The relation plainly is that of actor to his action.

Very differently, in the order (or commandment)

Ride the horse

the riding and the horse must be in some relation — doubtless that of action to what it affects—to the actee, the horse.

Now it is these relations that our grammars vaguely and perhaps exclusively perceive, as respectively relation of a subject to its verb, and that of verb to object. As to their exactness in perceiving, given merely

The jockey   the horse,

the grammars seem to presuppose e.g. a dialogue of this sort:

What does the jockey do?
He does a riding.
What does the riding do?
It affects the horse.

It seems to me, however, that the layman would not thus meander — would go straighter to the mark by asking

What have the jockey and the horse to do with each other?
How are they related?

and should get the answer

They are in the actor to actee relation (in the act of riding);
They are in the rider-to-ridden relation;

that is, minds that have not been sophisticated take the short-cut straight from first to last term, through the mid-term.

But, in

The jockey riding the white horse,

short-cuts have no chance. The choice of "rid*ing*" instead of "rid*es*" is warning that it's not the mid-term of the judgment whose expression has begun; that, whatsoever mid- and last term may be coming, they have not arrived; that in the judgment there will be no place for "riding" save as an adjunctive. Accordingly, as an adjunctive, it *immediately* operates; an instant later might be too late for effective organizing of ideas — particularly organizing by the hearer.

Let

The jockey *riding the white horse*

be now compared with

The jockey *on the white horse.*

Obviously the two expressions are essentially equivalent; and, in the two, the phrases in italics are alike adjunctive to the subject "jockey".

In the first, it was apparent that the "riding" was at once associated with "The jockey" — did not wait for the arrival of the "horse"; (There might indeed have been no horse to wait for, as for instance in "The jockey riding in the green coat won the race.")

In the second, "on" can hardly thus associate itself at once with "jockey". "Jockey on" is rather senseless till we know "on what." It seems to me we wait to learn the total meaning of the adjunctive phrase, before associating any part of it with "jockey" — that we then therewith associate it as a whole.

The following illustration gratified the feminine contingent at a lecture.

Leaving the house for an evening stroll which may be chilly, Mrs. hooks an arm imprimis to the arm of Mr. After that, she catches on her other arm her nearby hanging opera-coat. The organizing of the Mr. - Mrs. - coat association is according to the method followed with the participle.

Suppose however that she first takes up the coat — that, next, this combination of the two connects itself with Mr.; organizing of the Mr.-Mrs.-coat association this time is according to the method followed with the preposition.

PART III. THE CONJUNCTION

Some distrust of Grammar in its treatment of this "Part of Speech" may be awakened first of all by its current definition as "a word that joins". At once the question rises: joins what? As the conjunctions actually do not join words (compare them with the hyphen) but rather separate them, probably ideas are intended. One more question: can ideas be joined, and — if so — do we wish to join them?

Given

Men and cabbages need light and water,

I see no means of genuinely joining men and cabbages, or water and light. Presumably you have no interest in joining light and water, and, if joined to a cabbage, would desire immediate disjunction. So too, of ideas corresponding or the words for them, if they were joined, we should wish them to be disjoined, to avoid embarrassment; thus e.g. if light and water should be joined, how could I make it plain — or even think within myself — that I have one of them but not the other.

Distrust of Grammar grows with learning that while some conjunctions join ideas (or words?) together, others join them apart — as Grammar puts it, are "disjunctive". It looks as if we might feel free, in dealing with this matter, to think for ourselves.

To utilize this freedom, let the following serve as a working hypothesis: genuine conjunctions indicate that the ideas "joined" are merely to appear in mind together — this in various relations, as may be apparent later.

Genuine junction is however common, as was argued in both "Pronouns" and "Connectives". To illustrate,

Here is the book you want,

in which omission of the so called "relative pronoun" hardly calls for an apology, as there are languages which have no relatives.

In this sentence one may find two propositions: the book is here, and you want the book. As argued in "Pronouns", the idea named by "book" is not twice thought: appearing first as part of one idea-structure, it holds its place in mind while further ideas gather about it to form a second structure.[16]

"Book" is plainly an indispensable factor of "The book is here": without it, what remains is valueless in thought-formation and communication. This is also true of "book" in "You want the book". Of things that have an indispensable element in common it is usual to say that they are joined — e.g. two chains with a common link; the like may plausibly be said of the given judgments (propositions) which may be exhibited as follows:

(Here is the [book) you want].

one judgment being bounded by the paranthetic marks; the other by the brackets; "book" appears between each pair of boundaries, as a factor of each judgment. "Book", then, may with maximum propriety be said to operate as a "conjunction".[17]

This however is not meant for devotees of Grammar. A rad-

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[16] It is worthy of note that if a relative pronoun is added after "book", this "pronoun" often merely serves as warning that the idea named by "book" is to be held in mind to enter into further thought-formation—often however also to foretell the idea's (factorship or) function in the second thought, as e.g. subject, object, operating therefore as a second, though detached, case-ending.

[17] Compare the interesting illustration quoted by Professor Paul—approximately:

("Up from his seat arose [Herr Hagen) spoke as follows.]"

ically different illustration may be more digestible; but let an intermediate pabulum be offered:

(1) He arrived the moment the clock struck twelve;

or, more elaborately,

(2) He arrived at the moment at which the clock struck twelve;

or, more compactly,

(3) He arrived then when the clock struck twelve;

or let the "when", as usually, have a double force, as in

(4) (He arrived [when) the clock struck twelve],

which obviously is built according to the plan of (1).

The "parsing" of "(the) moment" I abandon to grammarians, imagining however that they would regard it as a noun, presumably obliquely understood, adjunctive to "arrived". I see indeed no reason why they should not also rank it as the adjunct (in a second fellowship) of "struck".

The idea expressed by it, like that of "book", is then an indispensable factor in each one of two idea-structures (in this illustration, propositions). In the first it names ostensibly the time of arrival, but is helplessly indefinite until, by its association with the striking, it acquires definiteness.

It is interesting to observe that, in the said acquiring, it violates the subject-copula-predicate doctrine, using "the clock struck twelve" as its distinguisher in its second factorship. This violation is perhaps a trifle more apparent in "Here is the book you want", in which "you want" is forced to serve as a distinguisher (restrictive attribute or accident) of the book at hand from other books.

To make this operation plainer, notice the equivalence of

(Here is the book) (subj.) — is (cop.) — desired-by-you (pred.)

and

(Here is the) you (subj.) — are (cop.) — desiring-book (pred.),

each one of which — the latter, with a shift of "book" from last place to the first — successfully distinguishes the book at hand from others, though the two expressions differ widely in their syntax. What is most important for the present is that "moment", being (in the judgment-forming) indispensable at once to his arriving and the striking of the clock, effectively unites them — operates as a "conjunction".

Plainly this is also true of "when", to which grammarians accord a partial recognition, sometimes ranking it as a conjunctive adverb (strictly twice adverbial) and — by virtue of its double indispensability — a joiner, a conjunction. In "Hybrids" it seemed plain enough that many a word may be two parts of speech at once, if the idea expressed by it is singly thought in double function.

As the promised radical illustration, let the following serve:

He lies as he fell,

which is intended to exhibit an identity of attitudes, or say positions, as exhibited for instance by He fell face down; he lies face down.

The syntax of this sentence is revealed by the history of "as", a mere abbreviation of "all so" in the sense of quite so, just so or exactly so. The illustration then expresses what, in two successive efforts, might have been expressed by

He lies just so;
(He fell just so);
Just so he fell.

In these the meaning of "just so" may be assumed to be in one case what it is in the other. One continuous thinking of what it expresses abrogates the need of re-expression, leaving

(He lies [just so) he fell].

an indefinite equivalent of

(He lies [on his face) he fell].

an exact equivalent of

(He lies [as) he fell].

Here again no doubt the adverb being indispensable to each of two statements, joins them — is a conjunction. So however did "(the) book", a noun. So also might an adjective, for aught I see. For instance, given

We are mortal(also) are our children,

there appears to be no difficulty in continuous thinking, as in

(We are [mortal) are our children],

or in even

(We [die) our children also].

We are nearing the conclusion that there is no warrant for imagining a special "part of speech" — a special conjunction-class — for "joining" seems to be an operation that may be performed by every other part of speech. To speak more cautiously, perhaps it will be found that each conjunction merely is another part of speech in a particular environment — only incidently conjunctive.

Another class of joiners, operating by a method thus far not examined, has been rather dimly recognized as "Thought-connectives" — more exactly, judgment-connectives.

To illustrate,

He invited me. Therefore I came,

which in "Connectives" was explained essentially as follows:

In this expression "There" (the leading syllable of "Therefore") reinstates in mind the waning judgment registered by "He invited me". This judgment, constituted by two terms and their relation (of inviter to invit*ee*) is a thoroughly coherent mental organism, eminently capable of serving as a unit in another judgment.

In this other judgment "There", as indicated, has the force of "his inviting me"; and "fore" (in the sense of for, from, by reason of, on account of) operates with "There" (in the sense of "that") as a prepositional phrase, adverbial to "came". Accordingly the meaning of the illustration is in detail

He invited me. On account of that (his inviting me) I came.

That is, the idea named by "fore" is the relation (of effect-to-cause) subsisting between two terms, my-coming and his-inviting-me.

"Therefore" may be said to join these terms, because the latter part of it is an indispensable factor of each — indeed, the whole of the first. The joining then is by incorporation, and invites a reference to the whole of Bible narrative, which doubtless in a manner joined Jonah to itself.

Joining of the sort (thus far) above exhibited grammarians hardly had in mind when offering their definition of conjunctions. Genuine though such joining is, it seems to have been vaguely understood and mainly overlooked. It remains to be examined whether what they call conjunctions really join. Of these let

"and",

as typical, be first examined.

In "Connectives", "and" (in operation as a joiner of two judgments registered by sentences) was thus interpreted: There being given

He invited me; I came;

if now it be desired to form these separated judgments into a coherent total, they are e.g. thus reconstituted:

He invited me; and I came;

the meaning of the "and" appearing more distinctly in

He invited me; *in* (concordant) *addition thereto* I came.

That is, the "and" revives in mind, as a mental unit, his inviting me; it further also calls upon the mental stage the idea of accession or accompaniment, or in other words a rather tenuous relation of the (at the outset) unaccompanied, and a companion — single (solitary) and the accessary — a relation which may be expressed by the mathematical + or "plus". It should be noted further that relation this time also runs from coming to inviting; it's the coming that is "plus". The "joining" is effected by incorporation of the "He invited me" in "and" interpreted as "in addition to his inviting me".

When now this "and" is said to join, not a pair of sentences (expressing judgments) but a pair of words (expressing ideas) the operation is in part analogous. For instance, given

pears and apples,

"apples" calls upon the mental stage an idea, to take its place beside the pears already there. It is unnecessary to revive in mind the pears; for these are not like "He invited me", which is a strictly selfsufficient mental entity. The pears alone are insufficiently important for communication. Further elements are necessary to a thought. One may assume accordingly that the idea expressed by "pears" has not begun to wane, is on the mental stage, is waiting — therefore not revived and not incorporated by the "and".

Beside the pears, then, now are brought the apples. But, as has been urged repeatedly, the importation of a word (or rather an idea) requires it to be in some relation with a word (or rather an idea) already on the spot; for otherwise the imported element would be unrelated, irrelevant — "have nothing to do with" already (established) accepted material. The relation, this time as before, is that of the (originally) unaccompanied and a companion — once more registrable by a +. Again relation runs from last to first. It is the apples that are plus.

In time however this relation, doubtless never quite distinct in mind, was presumably "seen double" — sensed as simultaneously running both ways — proverse and reverse. Stated otherwise, it came to be conceived that the association of the apples with the pears should yield to a consociation of the two.

By way of illustration, it would far from please me to interpret.

You and I are gentlemen

as

You — "me too" — are gentlemen.

I want that equal recognition of us both that is exhibited by

We are gentlemen.

I want the "you and I" to have the double value of "I plus you" and "*you plus I*", as seems to be suggested by the ranking of the "and" as a "*co*-ordinate" conjunction—one that puts the "joined" elements on all ways equal terms.

The relation then of pears and apples may be redefined as that of a member to member of a group — more briefly, the comembership relation. And even this relation is presumably but dimly sensed when the completely equalized prestige of the related elements has once been recognized. "And" apparently has lapsed into the rank of a mere group-sign. Somewhat similarly the plural ending *s*, which might mean "two or more", is operative rather as a rudder than as the expression of an added meaning. "Pears" instead of "pear" should steer me to the many from one, somewhat as the capital in "Jimmy" steers me from the burglar's implement. We do not seem to think the capital or the *s*. Each one of them appears to function rather as a guide-board than as part of the mental road traversed. We merely recognize that we are in the one case to think of a man and not a tool, and in the other of more than a single pear.

The difference between a group, as the word has been employed, and a plural, should perhaps be emphasized, as it appears to be the *raison d'être* of the "and". A "plural" must be homogeneous; in actual practice our linguistic "groups" are not. One may indeed amuse himself with forming homogeneous groups, e.g. "an apple and another apple"; but construction of this sort is surely limited. The group exhibited for instance by "a pear and an apple" is formed because one can't induce them to become a plural — or say two — of either kind: they aren't two anything, unless you choose a less specific kind, for instance "fruits", that will admit them both — a plural or a pair, in which however they must sink their differences — be no longer differentiated as a pear and an apple.

As a rule the thought-connectives and group-formers fail to be distinguished by grammarians, although they operate by different methods. Thus, in a list with the group-forming "and", I find both "too" and "also". But, in, e.g.,

pears also apples,

the mental operation seems to be that registered by

pears, in addition thereto apples;

that is, "pears" this time appear to be withdrawing from the mental stage, and therefore to require a recall, as was the case with "and" employed as a thought-connective — rather a judgment-connective — operating by incorporation. Leastwise this much seems to be assured: the "also" has not yet acquired the ability of "and" to group the apples with the pears on equal terms; they make their appearance as a supplement, an afterthought or side-thought, as suggested by the usual punctuation, which appears in

pears, also apples.

It would seem then that the "also", commonly a thought-connective, should be ranked in this case too as a "connective", though it this time operates upon ideas, not thoughts.

Similarly

pears, apples too

exhibits apples as a supplement, and emphasizes this by the position of the "too".

The initial stages of development along the lines described might be regarded as illustrated by

"He is good friends with me",

a popular substitute for, a variant of,

He and I are good friends,

which might be ranked as a mere distortion of

He with me are good friends,

the choice of "is" instead of "are" resulting from preponderating influence of "He" in the absence of the belated "me". The

He with me

would then be a mere duplicate of

He and I,

both phrases meaning at the outset He plus I — the former paraphrasable by

He in addition to me;

the latter by

He, in addition I.

It is however possible — perhaps more probable — that the quotation is a modified expression of what at first was differently formed in mind — expressible by

He is a friend to (or friendly with) me,

from which an ordinary swerving, mental or expressional, would lead to

He is a friend with me.

Now the quotation presupposes careless thinking, which may well have been befuddled by the coming "me", presumably in mind from start to finish. This "me" with "He" suggests the plural "friends", intensified by "good", but obviously untenable as before with "He is".

To throw a little further light on group-formation, another illustration has just arrived:

> "Modern warfare with aircraft and submarines
> have made Gibraltars more and more obsolete."

In this it may be that the growing journalistic tendency to make the verb agree in number with the noun last mentioned, is alone to be reckoned with; or "warfare with aircraft" may be meant as the equivalent of aerial fighting. But as other similar, unambiguous illustrations not recorded or remembered have exhibited analogous group-formation, I elect the meaning registered by

Modern warfare, (together) with aircraft etc.

in which the "modern warfare" indicates the general change in military strategy. Accordingly the grouping is accomplished by two different processes: an "and", in the usual manner, forms an aircraft-submarine group; this group is then, by means of "with", made member of the supergroup expressible by warfare plus aircraft-submarines, which properly is followed by the plural verb-form. The illustration parallels accordingly the

"He is good friends with me" (of p. 217).

except that in the present case the group-formation is distinctly indicated by the plural verb-form.

That the intention of an "and" group is to put its members on an equal footing is suggested by

Both pears and apples,

in which "both" insists as much on the admission of one member as on that of the other.

A similar result is reached by repetition of the Anglo-saxon alternate of "and" in

ge . . . . .ge,

and in the Latin equivalent

et . . . . et,

the operation finding an analogue in Spanish use of the interrogation point before, as well as after, a question.

The misplacement of the "and"-equivalent in

"Integer vitae, scelerisque purus"

is almost as obvious as it would be in

"Senatus populus Romanusque";

for the poet's purpose was presumably to "join" "integer" and "purus".

Among "conjunctions" "that" is entered in some lists, and in two different functions, thus, *imprimis* as declared to be illustrated by

"I heard that the Greeks had been defeated by the Turks",

though my authority explains this sentence by

"The Greeks had defeated the Turks, I heard that",

which admirably indicates the *meaning* of the alleged conjunction. As for its in any sense conjunctive *function,* many have expressed their doubts.

It seems to me beyond debate that this "conjunction" is a substantive, demonstrative, in the accusative (objective case); that what comes after operates together also as a substantive; and that the latter was presumably at first distinctly felt to be in apposition with the former — or to be, in other words, a definite exhibiter of what indefinitely was prefigured or forerun by "that."

Presumably however "that" in time became no more than a sign that what was further to be said should be accepted as, in function, substantive — a sign that helps exact interpretation, though not often necessary, and quite often not employed.

The effectiveness of such a sign is based upon the very elementary principle that any word that needs another word or phrase to help it is a sign that one is coming: "that" alone is inefficient and requires an efficiently explanatory supplement which in the syntax naturally operates (as a "part of speech") like that which it explains; such elaborate explanation as is offered in e.g.

I heard *that, by which I mean* the Greeks, etc.

is possible, but hardly plausible. The game isn't worth the candle.

"That" in the other function is declared to be illustrated in

"These things I have said that ye might be saved",

in which the alleged conjunction further is declared to mean "in order that" — or, say, to be an equivalent of Latin "ut" — "which nobody would deny". Once more then "that" is a demonstrative and substantive, but this time dative, as appears in the Anglo-saxon "to tham that"— in English "for this (purpose) that".

How an indefinite substantive, succeeded by a definite-making clause, can be conceived in either cited case as having joining power, let the authors of the strange conception tell. As well rank "this" as a conjunction in

"I tell you this; you cannot gather figs (grapes) from thistles,"

in which whatever joining be done, is done as well without the help of "this" as with it. Further compare

I must say *one thing:* I am hungry,

etc., etc.

The well-known lapse of words from the expression of ideas (judgment-factors) into operation as mere signs of functions in a judgment-forming, is apparent in e.g.

"I want to be an angel",

in which "to", as often also "zu" and "de" or "à", is operative merely like a substantive derivative ending, as in "perte" from "perdre".

In "das Geben", the article does equal service — or, without the article — the initial capital itself. Analogously in

My striving was in vain

the adjective "my", although retaining all its meaning, is a sign that "striving" must be taken substantively, while in

Striving with all my might I failed

the striving obviously is a (verbal) adjective, or "participle", adjunct of the "I".

In the illustration given, plainly "this", "thing", "to", etc., "das" and "my" confirm the principle announced with "that" — to wit: a word that needs a supplement or follower is sign that one is coming.

Now and then the question arises, "On what does the conjunction operate?". Given

"It will be regarded and rightly as a menace"

the question rises: what does the conjunctive "and" conjoin?

I seem to recollect an effort to explain expressions of this sort by, e.g.,

It will be regarded . . . and it will be rightly regarded . . .

But the explanation hardly seems to explain. The variant

It will be regarded ... and the regarding will be right

is hardly more explanatory, but suggests an explanation possibly more tenable. For it distinctly hints that the regarding is conceived as having more than the single attribute expressed by "right". Perhaps this attribute is part of what is meant by "It will be regarded". Taking inventory seems to be in order.

"It will be regarded", naming a particular action, obviously exhibits it as passive, future, posed as actual (compare "will be" and "will *not* be") and as believed by me to be true (compare "will be" and "*to* be"). Of all these meaning-elements the truth or actuality of the regarding, it seems to me, is what is joined with rightness, as appears in the reorganized equivalent. The regarding (of it) as a menace will be actual and right.

The imaginable

"It will not be regarded, and rightly"

seems to offer greater difficulty, and perhaps to contradict the offered explanation. But the case impresses me as merely one of what may be conceived as an infinitive *not* split, which ought to be split.

It will be not regarded and rightly

expresses readily enough the actuality and rightness of a not-regarding.

It would seem then that the conjunction, so far as it claims a special power, belongs with the Gyascuticus and Hippogriff; or, as the astonished beholder of a camel (or may-be it was a giraffe) exclaimed: "There ain't no such animile!"

NOTE ON THE EVALUATION OF A SERIES

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In the study of the influence of higher harmonics on the indication of an electrodynamometer type of wattmeter the following series occurred: $1+\frac{1}{9}+\frac{1}{25}+\frac{1}{49}$, etc. The question naturally arises, what is the sum of such a converging series?

The equation for a rectangular e.m.f. wave is

$$e=E \sin \omega t+\frac{1}{3}E \sin 3\omega t+\frac{1}{5}E \sin 5\omega t+ \quad \text{etc. to infinity.}$$

In this expression E is the maximum value of the fundamental of the harmonic series and e is the instantaneous value of the e.m.f. wave. The maximum value of e in terms of E is obtained by substituting $\frac{\pi}{2}$ for ωt. When this is done

$$e \text{ max.} = E(1-\frac{1}{3}+\frac{1}{5}-\frac{1}{7}+\frac{1}{9}-\text{ etc.})$$

But $$\Theta = \tan^{-1} x = x - \frac{1}{3}x^3 + \frac{1}{5}x^5 - \frac{1}{7}x^7 + \text{ etc.}$$

and when $\Theta = \frac{\pi}{4}$, $x = 1$.

Hence $$\frac{\pi}{4} = 1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} \text{ etc.}$$

and $e \text{ max.} = \frac{\pi}{4}E.$

If an e.m.f. wave of the form

$$e = E \sin \omega t + \frac{1}{3}E \sin 3\omega t + \frac{1}{5}E \sin 5\omega t + \text{ etc.}$$

and a current wave of the form

$$i = I \sin \omega t + \frac{1}{3}I \sin 3\omega t + \frac{1}{5}I \sin 5\omega t + \text{ etc.}$$

be passed through an electrodynamometer type wattmeter, it is well known that the average deflection or torque is the result of the interaction of the e.m.f and current harmonics of the same frequency. The power indicated by the wattmeter is then given by the expression

$$P = \text{average } EI[\sin^2 \omega t + \frac{1}{9}\sin^2 3\omega t + \frac{1}{25}\sin^2 5\omega t + \text{etc.}]$$

$$= \frac{EI}{2}[1 + \frac{1}{9} + \frac{1}{25} + \frac{1}{49} + \text{etc.}]$$

But if the two waves are rectangular, then

$$P = e_{max}\, i_{max} = \frac{\pi}{4}E \cdot \frac{\pi}{4}I = \frac{\pi^2}{16}EI.$$

Hence $$\frac{\pi^2}{16}EI = \frac{EI}{2}[1 + \frac{1}{9} + \frac{1}{25} + \text{etc.}]$$

and $$\frac{\pi^2}{8} = 1 + \frac{1}{9} + \frac{1}{25} + \frac{1}{47} + \text{etc.}$$

By exactly a similar process of analysis, it can be shown that

$$\frac{\pi^4}{96} = 1 + \frac{1}{3^4} + \frac{1}{5^4} + \frac{1}{7^4}, \text{ etc.}$$

THE SULFUR MONOCHLORIDE REACTION OF FATTY OILS. II. ON THE NATURE OF THE REACTION PRODUCT*

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

When sulfur monochloride reacts with the saponifiable oils the accompanying phenomena which are obvious to the casual observer are (1) the liberation of a gaseous by-product, hydrogen chloride, (2) an appreciable heat of reaction and, (3) if the concentration of the former is sufficiently high, solidification of the reaction mixture. The last two observations have served as points of departure for practically all of the research in this field. Around one was developed an analytical procedure (1), now discarded, for the identification of fatty oils, whereas the other assumed some technical importance in that it is fundamental to an industry producing substances superficially resembling rubber and known as white factice or rubber surrogate. Historically the latter was developed first.

The discovery of the reaction between certain of the fatty oils and sulfur chloride[1] by which the former are converted into white factice, seems to have been accidental. Conflicting claims for priority (2) disclosed the announcement by Nicklès (2c) that he, in attempting to seal with olive oil the stopper of a bottle containing sulfur chloride, had observed (3)[2] the formation of this substance wherever the vapors of the former had come in contact with the oil, and that Rochleder (4) had also

* Presented in abstract under the subtitle "On the Nature of the Reaction Product" before the Division of Agricultural and Food Chemistry of the American Chemical Society, Cincinnati meeting, Sept. 8-12, 1930.

[1] This name is here used in this form because the authors in question did not describe the compound which served them in the reaction. Since the words *Chlorschwefel* and *chlorure de soufre* were in vogue during this period as descriptive of the monochloride, it is not improbable that this compound of sulfur is the relevant one.

[2] This statement is unaccompanied by any supporting literature citation except as herein reproduced. We have been unable to verify it.

called attention to this peculiar reaction. Parkes, to whom industry owes the process of the so-called "cold" vulcanization (5) of rubber, before that discovery was announced had made observations (5a) which apparently were substantially the same as those of his predecessors.

The earlier work in this field was largely descriptive and qualitative in nature. Nothing on the mechanism of this reaction appeared for approximately forty years. It was then that the view (6) was expressed that there are formed in this reaction glyceryl esters of sulfo-chlorinated acids, compounds from which the chlorine may again be readily recovered, but not so the sulfur. Such a conception of this reaction postulates that sulfur monochloride has a symmetrical structure and that two molecules of a glyceride combine with three of the former to the end that an addition compound (7) results after the manner of the reactions of the olefins (8). Henriques (9), relying upon the iodine number as indicative of the degree of unsaturation of white factice, concluded that this substance is the result of a simple addition reaction. Data obtained in this Laboratory by another method of approach suggest that the mechanism of this reaction is more involved than the foregoing statement implies.

Experimental

Attempts were made to treat 100 g. of fatty oil at room temperature (20-22°) with S_2Cl_2 (d_{25} 1.67328; $b.p._{28mm.}$ 41°) in an amount just sufficient to form a pulverulent, dry, non-sticky mass. Eleven groups of authentic oils, represented by nineteen members whose degree of unsaturation classified them as either drying, semi-drying or non-drying, were used.

Five oils in the list—beef tallow, palm, neatsfoot, cocoanut and sperm — did not yield solid products even with the high concentrations of S_2Cl_2 indicated. The experiment with soy bean oil was abandoned after the addition of 16 cc. S_2Cl_2 failed to produce a reaction product suitable for further observation. The resulting products from six of this number were then exhausted with chloroform under conditions which admitted of a quantitative determination of the soluble material (free sulfur, unaltered fatty oil constituents, etc.) and the insoluble, or true factice (Table II).

TABLE I. *Minimum Volume of Sulfur Monochloride Required to Convert One Hundred Grams of Fatty Oil into a Solid Reaction Product.*

Oil	Iodine number	S_2Cl_2 cc.
Cocoanut*	9.3	24
Beef tallow*	38.8	20
Palm*	52.4	20
Lard (oil)	64.0	16
Neatsfoot*	72.9	24
Sperm (wax)*	78.5	24
Castor	82.2	12
Olive	87.8	12
Peanut	91.2	12
Almond	94.3	16
Rapeseed	100.7	12
Cottonseed	110.8	14
Corn	117.0	14
Soy bean*	123.7	16
Whale	131.0	12
Menhaden	142.2	14
Tung	157.6	12
Cod liver	159.0	12
Linseed	186.8	18

*Reaction product with indicated volume of S_2Cl_2 is a liquid.

TABLE II. *Analyses of Factice*

Source	Insoluble in $CHCl_3$ per cent*	Sulfur Theory %	Sulfur Combined %	Chlorine Theory %	Chlorine Combined %
Olive oil	86.70	9.76	9.70	8.83	5.63
Rapeseed oil	77.80	9.76	9.74	8.83	5.69
Cottonseed oil	78.60	11.19	9.74	10.13	5.70
Corn oil	76.30	11.19	10.54	10.13	5.63
Tung oil	69.20	9.76	9.72	8.83	5.60
Codliver oil	62.40	9.76	9.73	8.83	5.56

*Based on weight of crude product.

The sulfur and chlorine (10) contents of each factice were determined by the usual methods with the aid of the Parr bomb.

DISCUSSION

If one assumes that the ethylene linkages in two moles (7) of oleic acid react with one mole of sulfur monochloride in the formation of an addition product, it is possible to assign to this acid a theoretical "sulfur monochloride absorption number" of 23.9.[3] From this it follows that one-hundred g. of the dry acid should absorb approximately fourteen cc. of sulfur monochloride (d^{25} 1.67328) without the evolution of hydrogen chlor-

[3] This expression is used here in a sense analogous to the iodine absorption number. It is calculated from theoretical considerations.

ide, an inevitable concomitant of substitution. Yet, in an attempt to measure under closely guarded conditions at what point, if any, addition is completed and substitution begins, it has been demonstrated (11) that hydrogen chloride is split off with much smaller concentrations than this of sulfur monochloride. The closest analogy to this reaction is that with the glycerides of oleic and like acids which for practical purposes simulate the fatty oils. It appears that there is a much greater tendency for substitution by chlorine than by iodine, a situation which renders difficult, if not impossible, a successful correlation of iodine absorption and sulfur monochloride values.

Further sustantiation of this observation may be found in the anomalous behavior (Table I) of the several groups of oils whose members bear some resemblance to each other in their physical properties or chemical natures. Here may be found oils of either low or intermediate capacity for the absorption of iodine aligning themselves with the so-called drying oils in their reactivity with sulfur monochloride and others of the former type yielding no factice even with twice as much of this reagent.

Further evidence for the statement that white factice is not the result alone of the interaction of sulfur monochloride and the glycerides of the unsaturated acids in a fatty oil and that substitution is an attendant phenomenon may be found on making an analysis of this product. Reliance had been placed (9) in the past upon the iodine number as indicative of the degree of unsaturation of factice. Observations (11) made in this Laboratory suggest that the determination of this "constant" cannot be satisfactorily made on factice, and particularly so on one containing some sulfur monochloride which, in the light of thermal measurements, an evolution of hydrogen chloride and precipitation of sulfur, has been found to be reactive with the components of either the Wijs or the Hanus iodine solutions (12). It was found on analysis (Table II) that, with but one exception, all of the sulfur which had been added in the form of its monochloride had entered into combination with the fatty oil but that the amount of chlorine bound in the molecule is less than the theoretical quantity added. The premise that the mechanism of this reaction rests upon addition alone requires that all of the chlorine should be accounted for as was the sulfur and that the theoretical values for the sulfur and chlorine content of the factice should be in the ratio 32 : 35.5 (S : Cl) or 1 : 1.11. This, however, is not the case. A part of the chlorine has escaped as hydrogen chloride. Substitution of chlorine apparently cannot be avoided because of the accompanying rise in temperature brought about by the conditions under which factice is produced. It is not improbable that addition of the former to the unsaturated linkages of the compounds in a fatty oil will take place at low temperatures (7a), but whether a factice will form under these conditions is problematical.

Summary

In an attempt to learn something of the mechanism of the reaction whereby a solid product is formed in the interaction of sulfur monochloride and fatty oils, evidence has been found which seems to point to the observation that the former is not the result alone of a simple addition process but that substitution is a concomitant phenomenon. The complex chemical nature of the fatty oils does not, in the light of present information, permit of a more definite picture of this reaction than is herein described.

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THE SULFUR MONOCHLORIDE REACTION OF FATTY OILS. III. A NOTE ON THE THERMAL BEHAVIOR OF THEIR FATTY ACIDS.

ELLERY H. HARVEY AND H. A. SCHUETTE

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

Lewkowitsch (1) once reported that there is a remarkable difference in the action of sulfur monochloride on fatty oils on the one hand, and on their mixed fatty acids on the other. He observed that oils are quickly acted upon by this reagent with the formation of a solid product, whereas their fatty acids respond more slowly yielding semi-solid viscous products. Supporting data are not presented nor is his *modus operandi* described. Because of these observations the question arose whether marked differences would also be apparent in the thermal effect accompanying this reaction when it is retarded by the presence of a diluent.

Apparatus, Materials and Procedure. The reaction flask consisted of a silvered 300-cc. Dewar flask 55 mm. in diameter and 160 mm. in height. A flanged Bakelite cap, drilled to accommodate a motor-driven stirrer, a thermometer and a pipet, respectively, served as a cover. The whole system was packed in kieselguhr.

The thirteen fatty oils used in this study were pure in the sense that they comformed in name to that for which sold, a fact experimentally verified. Their mixed fatty acids were isolated by the procedure recommended by the Association of Official Agricultural Chemists (2) as part of the determination of the titer test. The sulfur monochloride was purified from a commercial sample as previously described (3).

The rise in temperature brought about by the action of the sulfur monochloride on the fatty oil or its acids was measured under the following conditions: 25 g. of the material under examination and a like amount of pure, dry xylene were weighed into the calorimeter, 1 cc. of the reagent at the same temperature as the former was quickly introduced (15 sec.), the stirrer was started and the maximum temperature rise and the time required to reach this point noted. Correction (4) was made for radiation losses from the surface of the liquid.

Results

Data obtained in this study are presented in the following table. They are recorded in the order of ascending iodine numbers of the fatty oils under investigation.

TABLE I. *Comparison of Thermal Rise of Xylene Solutions of Fatty Oils and their Insoluble Acids when Treated with 1 cc. of Sulfur Monochloride*

Fatty oil	Maximum rise in °C.		Time in minutes		Rise per min. in °C.	
	Oil	Acids	Oil	Acids	Oil	Acids
Palm	12.9	7.2	20	15	0.64	0.48
Lard oil	16.0	17.9	55	40	0.29	0.44
Neatsfoot	16.1	18.0	50	35	0.32	0.51
Castor	17.5	18.6	8	4	2.10	4.65
Olive	10.0	17.1	165	27	0.06	0.63
Rapeseed	14.3	16.6	75	20	0.19	0.83
Sesame	11.7	17.9	75	21	0.15	0.85
Corn	11.9	17.6	100	18	0.12	0.97
Soy bean	12.5	18.1	100	35	0.12	0.54
Menhaden	18.3	18.4	25	13	0.73	1.41
Tung	13.5	13.0	50	6	0.27	2.16
Codliver	13.4	17.2	45	18	0.30	0.95
Linseed	17.3	19.8	65	13	0.26	1.52

It is of interest to note that the thermal behavior of the fatty oils and their fatty acids was found to be reversed with respect to the reaction which Lewkowitsch studied. When viewed in the light of the time required to reach the maximum point of temperature rise, it appears that the action of sulfur monochloride upon the fatty acids is more energetic than upon the parent oil itself. This condition is also pertinent to the rise of temperature per minute.

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THE SULFUR MONOCHLORIDE REACTION OF FATTY OILS. IV. ON THE EVOLUTION OF HYDROGEN CHLORIDE.

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

In attempting to adapt the exothermal feature of the sulfur monochloride-fatty oil reaction to the identification of the latter, Fawsitt (1) observed that hydrogen chloride was evolved more or less copiously. The results which he noted in a qualitative way led him to state in substance that the action of this reagent on those oils which bear some similarity to each other with respect to physical properties and chemical natures apparently follows no rule in that some caused the liberation of a large volume of gas whereas others produced none at all; nor did there appear to be much, if any, regularity in the nature of the reaction product or the thermal effect accompanying its formation.

The evident desirability of verifying these observations quantitatively prompted us to re-investigate this phase of the reaction. This objective was approached by the development of an analytical procedure resting upon the use of highly purified sulfur monochloride, thoroughly dried fatty oils, a relatively inert solvent, and a suitable gas-evolution apparatus. Chloroform was adopted for use as solvent after it had been experimently demonstrated that it is superior in this reaction to carbon tetrachloride and to xylene.

In the course of this work the need arose for an expression which will briefly describe the measurements which are herein recorded. Following the practice which obtains in fatty oil chemistry, where the use of the words "number" or "value" is in vogue, the expression "hydrogen chloride value" was adopted. Wherever used throughout this communication it means *the number of cubic centimeters of tenth-normal alkali solution required to neutralize the hydrochloric acid evolved in one hour by* *the action of one cubic centimeter of pure sulfur monochloride on twenty-five grams of dry fatty oil or wax dissolved in a like quantity of dry chloroform.*

EXPERIMENTAL

Materials. For experimental material there were selected twenty-four fatty oils representative of ten groups in the classification of Mitchell (2). Their purity in the sense that they conformed in name to that for which they were sold, was experementally verified. They were thoroughly dehydrated by heating them in a high vacuum over phosphorus pentoxide. The chloroform was dried over fused calcium chloride and re-distilled while the sulfur monochloride was purified after the manner of Pope (3) by distillation in the presence of sulfur and highly absorbent charcoal. Its physical properties have been described elsewhere by us (4).

Apparatus. The apparatus which served in this study was a combination of aspirator and reaction flask. The latter consisted of a stoppered, opaque glass chamber, 50 x 150 mm. in dimension. It was provided with an inlet tube reaching almost to the surface of the reaction mixture, a mercury-sealed mechanical stirrer, a burette, and an orifice for sucking out the gaseous by-products. The inlet tube was in direct union with a drying train comprising in turn, two wash bottles — one for sodium hydroxide solution, the other for sulfuric acid — a drying tower filled with phosphorous pentoxide, and a third wash bottle containing dry chloroform, the object of which was to saturate the incoming air with this solvent before it entered the reaction chamber. By means of the outlet tube the mixture of air and gaseous reaction products was first led through chloroform for the purpose of absorbing any sulfur monochloride vapors which might have passed over with the gas stream, and then absorbed in a measured volume of 0.1 N sodium hydroxide solution contained in a wash bottle. Between the latter and the aspirator pump was interposed a flow meter for measuring the rate at which air was being drawn through the system.

Method. Exactly 25 g. of the dry, filtered fatty oil and a like quantity of anhydrous $CHCl_3$ were weighed into the reaction chamber which was then sealed into the aspirator train and set into a thermostat at 25°C. Thereupon the air current was adjusted so that 665 cc. passed through the system per minute, the stirrer was started and finally 1 cc. of S_2Cl_2 (d^{25}, 1.67328) was introduced through the burette.

The reaction was interrupted at the end of one hour after which the volume of hydrogen chloride which had been evolved during this time was determined by titration. That the gas in question was actually hydrogen chloride was verified by gravimetric analysis.

The reaction pertinent to this communication was studied from the standpoint of (1) a general survey of the behavior of fatty oils under a standardized procedure as outlined above, (2) the effect of light upon the rate of evolution of hydrogen chloride, and (3) the probable application of this reaction to the analysis of mixtures of oils.

TABLE I. *Hydrogen Chloride Values of Fatty Oils*

Fatty oil	Iodine number	Acetyl value	HCl value
Cocoanut	9.3	16–16.8†	10.9
Butter fat	30.0	15.7*	7.5
Cocoa butter	35.7	—	7.1
Beef tallow	38.8	1.9*	2.7
Palm	52.4	19.2†	6.5
Lard	58.1	1.9–8.6*	3.6
Lard (oil)	64.0	2.7–8.6*	3.7
Neatsfoot	72.9	7.7–9.3*	5.8
Sperm (wax)	78.5	4.5–6.4*	8.7
Castor	82.2	146–150*	5.3
Olive	87.8	11–23*	5.7
Peanut	91.2	3.5*	0.8
Almond	94.3	9.6*	0.7
Rapeseed	100.7	14.7*	8.5
Sesame	103.3	9.8–11.5†	0.6
Cottonseed	110.8	21–25*	0.6
Strammonium	116.2†	—	0.5
Corn	117.0	7.5–11.5*	1.6
Soy bean	123.7	4.9*	0.5
Whale	131.0	11–23*	14.0
Menhaden	142.2	—	7.3
Tung	157.6	—	0.0
Cod liver	159.0	1.1*	8.8
Linseed	186.8	9.8†	0.0

*Hodgman and Lange, "Handbook of Chemistry and Physics", Chemical Rubber Publishing Co., Cleveland, **1930**, 5 ed. p. 472.

†Value taken from Grün and Halden, "Analyse der Fette u. Wachse", Julius Springer, Berlin, **1929**, Vol. II, p. 151.

RESULTS

General survey. The study of the evolution of hydrogen chloride, as defined by the method herein employed for its determination, brought out some interesting though inconsistent, relationships. The data (Table I) pertinent thereto admit, in substance, of no more definite conclusions than were drawn as a result of our repetition of Fawsitt's thermometric experiments (5) during the course of which some fundamental improvements in technique were introduced.

If the ethylene linkages, or other sources of unsaturation, were alone concerned in the sulfur monochloride-fatty oil reaction, evidence for this would be reflected in the data obtained in that the relation between iodine numbers and hydrogen chloride values would in any series be an inverse one. This condition, however, is not markedly noticeable in the group of oils here under investigation. The volume of hydrogen chloride evolved is evidently not a true measure of substitution nor yet of addition. It appears that both reactions take place concurrently, the drying oils, tung and linseed, with zero values being, in this instance, an exception.

The non-drying vegetable oils, castor, olive, peanut, almond and rapeseed, although representing only an eighteen point difference in iodine numbers, show no general concordance in hydrogen chloride values. The reactivity of sulfur monochloride with sterols and other forms of hydroxylated compounds known to exist in fatty oils, makes unique the comparatively low hydrogen chloride value of 5.3 for castor oil, with an acetyl number lying between 146 and 150, in comparison with that of 8.5 for rapeseed oil which has an acetyl number of only one-tenth as much. A better agreement lies in the semi-drying group, represented in this study by sesame, cottonseed, strammonium, corn and soy bean oils. Here corn oil is the exception, a condition which can probably be traced to its sterol content. The vegetable fats, cocoanut oil, cocoa butter, and palm oil show a decreasing hydrogen chloride value with an increasing iodine number, yet lard proves the exception in the animal fat group which comprises here, in addition to it, butter fat and beef tallow. The fish and marine animal oils, whale, menhaden and cod liver, whose iodine numbers are of the order of magnitude of the drying oils, show in distinction from them unusually high hydrogen chloride values. There are without doubt other reactive groups in these oils which tend to increase this "value".

Effect of light. The knowledge that some chemical reactions are catalyzed by light and that addition reactions in halogens are frequently best controlled in the absense of sunlight prompted a brief study of the photochemical effect of the actinic rays of the sun in this instance. The reaction chamber

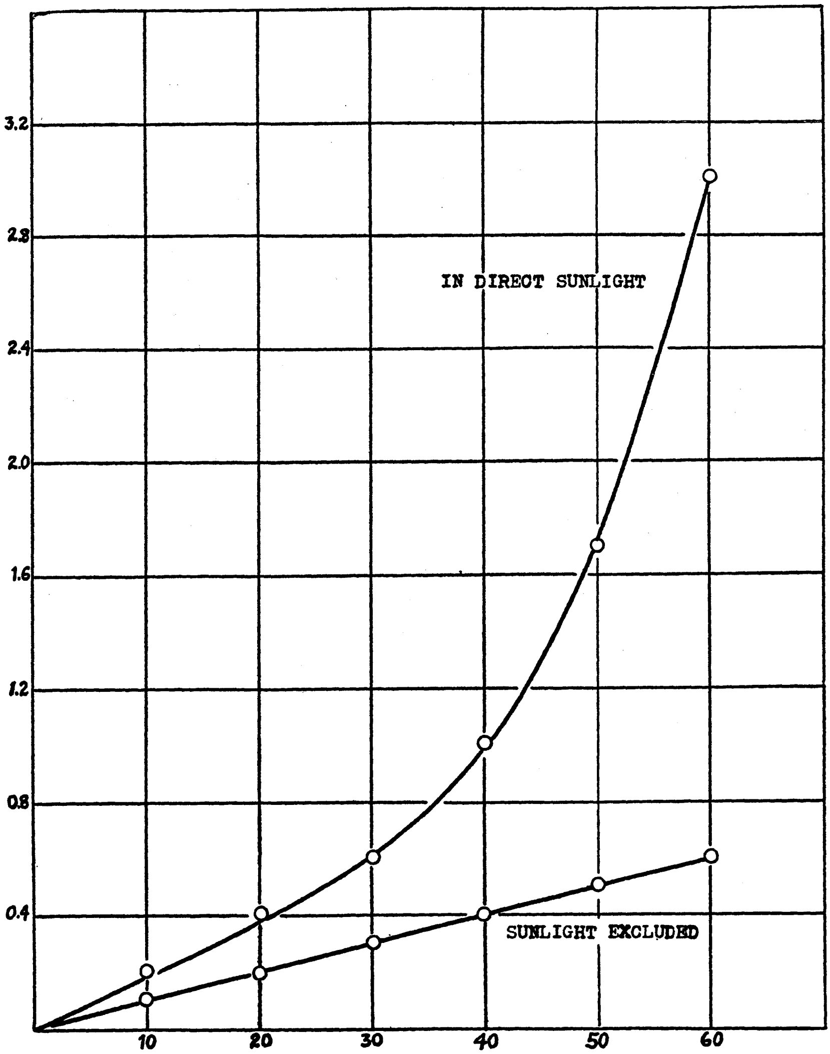

FIG. 1. Effect of sunlight in promoting substitution in the action of sulfur monochloride on cottonseed oil. The ordinates represent volume of hydrogen chloride evolved in cc. 0.1 N alkali equivalent. The abscissae represent time in minutes.

was immersed in the thermostat while direct sunlight was allowed to play on the surface of the reaction mixture within. The absorption chain was divided into two lines in such a way that one-half could be cut out without interrupting the hydrogen chloride-laden air stream. This device made possible the determination of the amount of hydrogen chloride which had been evolved at the end of any given time interval.

The necessity for excluding light from the reaction chamber as a means for reducing the tendency for substitution is illustrated (Figure 1) by a typical case in which the hydrogen chloride value of cottonseed oil was determined under the foregoing conditions. Readings were taken at ten-minute intervals.

Application to fatty oil mixtures. The possibility of applying the determination of this value to the analysis of mixtures of fatty oils, thereby aiding in the detection of adulteration, was

TABLE II. *Hydrogen Chloride Values of Fatty Oil Mixtures.*

Mixture	HCl Value	
	found	calculated
Olive-cottonseed	1.9	3.1
Olive-corn	1.8	3.6
Olive-sesame	1.2	3.1

given some consideration. Three synthetic mixtures of olive oil with cottonseed, corn and sesame oils, respectively, were made in the proportion of equal parts by weight of each. The hydrogen chlorides (Table II) were not found to be additive. Approximately one-half of the calculated amount of hydrogen chloride was liberated. It is obvious that the measurement, as herein defined, of the quantity of hydrogen chloride evolved by a mixture of fatty oils has little if any diagnostic significance.

SUMMARY

During the reaction between sulfur monochloride and fatty oils there is an evolution of hydrogen chloride. In an attempt at a quantitative determination of this gas by means of a standardized technique which gave rise to a so-called "value", itself defined by the method of procedure, there were obtained data which bear little, if any, relation either to iodine numbers or to acetyl values. The non-specificity of sulfur monochloride for the unsaturated linkage is the apparent cause of the anomalous behavior of this reagent with the fatty oils. Absence of sunlight retards, but does not prevent, substitution from proceeding concurrently with addition.

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MORPHOLOGICAL STUDIES OF ERYSIPHE AGGREGATA ON ALNUS INCANA

Erna A. Wentzel

The powdery mildews offer especially favorable material for the study of the development of the perithecium. The following study was undertaken for the purpose of extending our knowledge of the group by an account of the development of the ascocarp and spore formation in the genus Erysiphe.

Review of Literature

The structure of the ascocarp and the stages in its development have been fairly well understood since the time of De Bary (1863) and the main points of his conclusions have been many times confirmed.

In his investigation of *Sphaerotheca castagnei* De Bary (1863) found that at the crossing point of two hyphae, or at the place where two neighboring hyphae touch, each hypha develops a small upright branch which is soon cut off by a septum from the parent hypha. One of these branches swells to an oval-oblong shape and becomes the oogonium. The other lengthens slightly and applies itself closely to the side of the oogonium, curving above it so that its end lies on the apex. The upper part is then cut off by a septum and forms the antheridium.

De Bary observed no breaking down of the wall between the antheridium and oogonium and so supposed that no conjugation took place; nevertheless he considered that these organs represented a true sexual apparatus and that the perithecium subsequently formed was to be regarded as the result of a sexual act. This last conclusion has been verified by the works of Harper and others.

Harper (1895) described the sexual apparatus for *Sphaerotheca castagnei, Phyllactinia corylea, Erysiphe communis,* and *E. cichoracearum,* and found them to arise in general in the same manner. He observed that the sexual apparatus is formed where two hyphae cross or lie close beside each other, thus the oogonium and antheridium arise as lateral branches from separate hyphae.

He also found that the oogonial and antheridial branches seem to arise simultaneously, becoming closely applied to each other and spirally twisted. The oogonium which is thicker and heavier from the beginning grows in length more rapidly than the antherid around which it bends. There is no evidence of any special differentiation in the cell from which the oogonium arises. The first division of the nucleus of the hyphal cell furnishes one daughter nucleus for the gamete and the other for the cell of the mother hypha (stalk cell).

The antheridial branch arises in the same fashion as the oogonium, but is more slender from the beginning. The unequal tendency to spiral twisting in the sexual branches, together with their unequal size, produces a structure whose appearance varies considerably. When the antheridial branch is cut off from the hyphal cell from which it arose, it contains a single nucleus. This nucleus divides and a cell wall is formed between the daughter nuclei, so that one becomes the nucleus of the antheridial branch and the other remains in the hyphal cell below. The nucleus of the antheridial branch now divides and one of the daughter nuclei migrates into the tip of the branch. The tip is then cut off by a cross wall and becomes the antheridial cell.

According to Harper (1895, 1905) fertilization occurs in Phyllactinia, Sphaerotheca, and Erysiphe in practically the same manner. He observed that the antheridium is closely pressed upon the oogonium, a little to one side of and generally above the apex of the latter. Their walls in the region of contact are flattened against each other and become closely united. A portion of the walls between the antheridium and oogonium is now dissolved in such a fashion as to form a circular conugation-pore leading from the antheridium to the oogonium. The protoplasts of the two cells which are brought into direct contact combine to form a continuous protoplasmic mass. The nucleus of the antheridium migrates through the conjugation-pore into the oogonium and approaches the egg nucleus. The male nucleus at this stage is somewhat smaller than the egg nucleus. Harper observed that the male nucleus moves past the egg nucleus until it appears on the side farthest from the antheridium. The two pronuclei soon come to lie side by side in the oogonium and are readily distinguished by their difference in size.

Further observation showed Harper that the entire contents of the antheridial cell does not enter the oogonium. The male nucleus apparently leaves the most, if not all, of its cytoplasm behind when it enters the egg.

The conjugation-pore leading from the antheridium into the egg cell is closed very soon after the passage of the male nucleus. After the fusion-pore is closed there is considerable material in the antheridium that degenerates into a dense structureless mass.

The fusion of the pronuclei occurs in the center of the oogonium and perithecial development begins at once after fertilization. The enveloping hyphae push out from the stalk cells and grow up around the oogonium and antheridium, applying themselves closely to their surface and following an irregular path, owing to the slight spiral twisting of the oogonium.

Harper (1905) showed that the antheridial cell in Phyllactinia becomes embedded in layers of the perithecium where it ultimately gelatinizes and degenerates.

Hein (1927) found, in *Sphaerotheca castagnei,* that the antheridium and its stalk cell become a permanent part of the primary envelope, in which they may be readily distinguished from the hyphal cells. In late stages the antherid and stalk cell can not be identified with certainty.

When the primary layer has completely enclosed the ascogone, the stalk cell swells to a circular shape and a second series of hyphae, internal to the first, grows up in a similar manner. These hyphae appear to wedge their way between the ascogone and the primary layer, as a result becoming somewhat pointed at their ends. In pushing upward these hyphae force the outer layer outward and away from the ascogone.

Later the hyphae of both series intertwine, completely growing together and thus forming a pseudoparenchymatous tissue. This name given by De Bary (1863) is one generally accepted. De Bary described in some detail the formation of a pseudoparenchymatous tissue in the development of perthecia in *Podosphaera tridactyla* and *Sphaerotheca castagnei.*

According to Harper (1905) in his work on Phyllactinia, the third layer begins to develop at a time when the curved ascogone does not completely fill the perithecial wall. Its cells at first push into the spaces around the ascogone and show no tendency to tangential flattening. Later, when the ascus begins to swell rapidly, they are pushed back so as to form a layer of cells of fairly equal size and shape.

The cells of the two outer cortical layers of the perithecium begin to show changes in their appearance. The cell walls become thickened and their contents slightly vacuolated. As the cells grow tangentially they leave no intercellular spaces between them. The hyphal cells adhere very closely and are in intimate contact throughout. They form a strong limiting layer against which the inner cells are flattened by the inflating asci. Ultimately the ascus develops a high turgor pressure which flattens the cells of the softer inner layer so that they become quite thin.

These inner, radially growing cells of the perithecium retain their protoplasmic content even to a very late stage, that is, until the spores are completely developed. They are large and rounded in the beginning and decrease in size with the growth of the ascus. The natural suggestion is that they are "nurse-cells" for the asci, such a condition being noted by Harper (1895).

Late in the season the cells of the outer layer become greatly flattened and lose their protoplasmic contents, the external ones becoming dark brown and forming the outermost wall of the perithecium.

The fertilized oogonium continues development at once. Harper (1905) called the structure resulting from the growth of the oogonium, the ascogonium. As it grows the ascogonium elongates and increases in diameter. It tends constantly to burst out of the enclosing hyphae, which by elongation and branching again enclose and cover over its whole surface. As the ascogonium increases in size, the fusion nucleus divides and there is a binucleate stage, lasting until the complete enclosure of the ascogonium by the enveloping hyphae. In Phyllactinia, according to Harper's observations (1905), cell division never follows this first division of the egg nucleus. The ascogonium remains one-celled and the nuclei continue to divide. He is not certain how many nuclear divisions may precede cell division, but, in the end, there is a row of from three to five cells. The ascogonium in Phyllactina when mature is a single row of cells, the penultimate one containing regularly more than one nucleus.

The next step in the development of the ascocarp consists in the formation of the ascogenous hyphae. These arise as lateral branches from the ascogonium. These branches arise relatively early in the development of the ascocarp in Phyllactinia, at a time when the ascogonium is enclosed by only about two layers of the perithecial cells. These ascogenous hyphae overlap and intertwine with each other so as to cover the whole upper part of the ascogonium. Thus it is difficult to trace a particular branch to its point of origin.

The ascogenous hyphae in Phyllactinia, according to Harper (1905), (in whole or in large part) arise from the penultimate cell of the ascogonium. The cells that are to become asci contain two nuclei. The remaining cells of both the ascogonium and ascogenous hyphae after cell division is complete are almost without exception uninucleated.

The young ascus regularly contains two nuclei. The asci now elongate rapidly in a vertical direction while the sterile cells of the ascogenous hyphae, with which they are connected below, undergo no further development. The asci occupy a central position.

The two nuclei in the ascus fuse to form the primary ascus nucleus. Then the ascus rapidly increases in size and thus flattens the inner layer of the perithecium. The primary nucleus persists until the ascus has reached its full development.

In *Sphaerotheca castagnei,* as shown by Harper (1895), where a single ascus is found, growth takes place as follows: At about the time when the two primary layers of hyphae have grown up from the stalk cell, the ascogonium begins to elongate and nuclear division takes place, resulting in the formation of a single, more or less curved, row of five to six cells. In the penultimate cell of this row, two large nuclei are always present, while the other cells of the row contain a single nucleus each. This penultimate cell is the ascus. It swells so that the apical cell of the series is pushed aside and downwards and is finally absorbed. As two nuclei fuse, the ascus increases rapidly in size.

In an attempt to discredit the results of Harper's study on Sphaerotheca, Dangeard (1897) investigated the same form and published a paper with numerous illustrations. In his paper he takes up two questions: 1. Does the ascocarp take its origin from a sexual apparatus consisting of an antheridium and an oogonium? 2. Are these sexual cells functional? According to the work of Harper (1895; 1905) and that of De Bary (1963) both of these questions are to be answered in the affirmative.

As to the first question Dangeard's figures are unmistakeable. There is a sexual apparatus formed consisting of an oogonium and an antheridium, which is the initial step in the development of the ascocarp of Sphaerotheca. Wager (1899) points out that Dangeard admits these facts, and that he repeatedly uses the term antheridium in naming the structure described as such by De Bary.

Dangeard agrees with De Bary that these male and female cells arise from separate hyphae and he is inclined to the view that the hyphae may come from separate mycelia. With the establishment of the existence of an antheridium and oogonium at the beginning of perithecial development, Dangeard's own doctrine is left entirely unsupported. In his entire paper on Sphaerotheca Dangeard appears to be seeking to establish his original proposition that the ascus functions as an oogonium, although the evidence of his observations is to the contrary.

To the second question as to whether the sexual apparatus described is functional, Dangeard replies in the negative. He fails to find any evidence of a conjugation-pore between the antheridium and oogonium. He claims to have examined so much material that his failure to find a conjugation-pore must be accepted as final and indisputable proof that it does not exist.

In spite of this apparent certainty, however, Harper is quite convinced that a more painstaking search and better methods would have brought to light the stages in development that Dangeard failed to find. De Bary attacked the problem with essentially the same methods of preparation as were used by Dangeard and failed at exactly the point at which Dangeard failed, that is, in discovering the conjugation-pore between the antheridium and oogonium.

Blackman and Fraser (1905), in their work on Sphaerotheca, observed no cases where the antheridial cell was without a nucleus while the oogonium was still unfertilized, nor any instances in which the antheridial cell still contained a nucleus when the oogonium showed two nuclei; neither did they observe any instances of degeneration of the nucleus in the antheridial cell.

Wager (1899) has pointed out the possibility that Dangeard had a parthenogenetic form of Sphaerotheca, but Harper is not inclined to accept this view. The latter is convinced that Dangeard failed to find the fertilization stages because of his methods of preparation.

Dangeard assumes that the nuclear fusions in the ascus are much more easy to find than those in the oogonium. Harper has found it just as easy to discover the conjugation-pore and true sexual fusion of male and female nuclei in Sphaerotheca as to find nuclear fusion in the ascus. Dangeard evidently considers the fact that the male nucleus is smaller than the egg nucleus prior to the fusion, as evidence that the former is degenerating. He also regards it as an inconsistency in Harper's figures, that the male nucleus at the time of fusion with the egg nucleus has become as large as the latter.

Harper found that the process of spore formation is especially well shown in asci of *Erysiphe cichoracearum.* The primary nucleus of the ascus increases in size and finally undergoes three successive divisions, giving rise to two, four, and finally eight nuclei and thus providing the nuclei for the eight ascospores which are subsequently formed.

According to Harper the polar aster from the third division persists in all eight nuclei for some time, but is most conspicuous in the case of the nuclei which are to be enclosed in spores. A beak is next pushed or pulled out from the nucleus. The rays become elongated during the process, and at the same time they fold over and combine side by side to form a continuous broad, umbrella-shaped membrane. The broad umbrella-shaped membrane gradually closes to form the ellipsoidal plasma membrane of the spore. The whole spore body is cut out of the previously undifferentiated cytoplasm of the ascus, by the formation of a new plasma membrane derived from the fibers of the polar aster and without the deposition of a cellular wall.

After the spore is completely enclosed, the remnant of fibers disappears from the region of the central body. The nucleus gradually regains its spherical or oval shape by drawing in the beak-like prolongation.

Thus there is the triple division of the ascus nucleus to form eight nuclei and finally the formation of ascospores by the process of free cell formation.

M. C. Sands (1907) obtained similar results in work on *Microsphaera alni,* a plant with which she did considerable work on nuclear structure. She shows that in all stages of the life cycle of Microsphaera the central body is a permanent structure of the nucleus and is the point of attachment for the chromatin.

In Phyllactinia, Harper (1905) gives a fairly continuous account of the existence of the central body and the maintenance of its connection with the chromatin material through the two nuclear fusions, which occur in the oogonium and in the ascus. It is also noted through a series of divisions in the ascogenous hyphae, the triple division in the ascus, and finally through the formation of ascospores by free cell formation.

Materials and Methods

In the present investigation pistillate catkins of *Alnus incana* infected with *Erysiphe aggregata* were collected by Dr. E. M. Gilbert in June, 1927, at Hayward, Wisconsin. The material was fixed in Flemming's solutions, the weaker solution in general giving the best results.

Sections were cut eight to ten microns in thickness and stained with Flemming's triple stain, except in a few cases where Haidenhain's iron-alum haematoxylin was used.

Observations and Discussions

The mycelium of *Erysiphe aggregata* is much branched and septate, each cell being uninucleated (fig. 1). The hyphal branches grow in all directions, so that in some cases dense masses of mycelia are produced.

After the mycelium has reached a certain stage of maturity, there are cells which grow at right angles to the mycelium. In the material examined these cells resemble very much those described by Harper. One of these upright branches is slightly larger than the hyphal cell from which it arises. This is the antheridial branch described by Harper. The other branch is somewhat larger and resembles the oogonial branch.

In some cases these upright branches are closely applied to each other, while in others they are twisted. Despite the fact that these cells resemble the sexual apparatus described by Harper (1895, 1905) for *Phyllactinia corylea, Sphaerotheca castagnei,* and *Erysiphe communis,* no actual fertilization was observed. With the exception of the supposed fertilization or fusion of the oogonial and antheridial nuclei, all subsequent stages are present, although the earlier stages are not so numerous.

Following the stage that Harper calls fertilization the prospective branches which are to form the perithecial envelope push out from below the larger of the two upright cells, which Harper calls the oogonium. These hyphae grow up and around these two upright cells, applying themselves closely to their surface.

While the first enveloping branches are pushing up from the base of the larger (oogonial) cell, the latter is also continuing its development.

With the first growth of this cell (oogonium) the (fusion) nucleus divides to form a binucleated stage, which lasts until the oogonium is completely enclosed by the enveloping hyphae. The oogonium remains one-celled for a time and its nuclei continue to divide. Septations are then laid down which separate the nuclei from each other. Thus we have at maturity a single row of from three to five cells (fig. 2).

The next step in development consists in the formation of the so-called ascogenous hyphae. These arise as lateral branches from the cells of the row that has just been formed. From just which cell or cells the ascogenous hyphae arise the writer has been unable to determine. It appears that many ascogenous hyphae bud out at about the same time. These develop into multinucleated branches of the ascogonium. The nuclei are soon separated by cell walls, except in certain cases in which two nuclei are included in a single cell, usually the penultimate one (figs. 3, 4, 5.) These binucleated cells will later become the asci.

Before the asci are formed the perithecium begins to show some differentiation in its hyphal layers. There is an outer layer of wide lumened cells, already showing some thickening in their outer walls. Within are two or three layers of rather thin-walled cells, smaller and more densely filled with protoplasm. The innermost layer of these is especially active; it grows and sends branches toward the center, crowding against the ascogenous hyphae, and becomes divided to form the so-called "nurse-cells" which are shown in figure 6.

In *Erysiphe aggregata* these "nurse-cells" are present from the time of the development of the ascogenous hyphae, until the maturation of the eight-spored asci. As the development of asci proceeds, the "nurse-cells" are present in decreasing number.

Meanwhile, certain binucleated cells of the ascogenous hyphae are developing into asci. With their growth, the "nurse cells" are crowded back and flattened between the asci and the perithecial wall (fig. 7).

The young asci when first recognizable are little larger than the other cells of the ascogenous hyphae. The ascus is about half-grown before the two nuclei fuse.

The asci grow to be swollen, oblong sacks and are pressed together and flattened upon each other in their middle regions. The nucleus lies in the middle of each ascus and toward the base. The lower part of the ascus is narrowed into a stalk; however, this narrow stalk is not separated from the ascus by a cross wall.

One of the most frequent and conspicuous stages seen in *Erysiphe aggregata* is that of the primary nucleus. M. C. Sands (1907) also found this to be a common stage in *Microsphaera alni.* It persists from the time of fusion of nuclei in the young ascus, until the ascus has reached its full development (figs. 7, 8).

By the time the uninucleate ascus is developed the perithecium has grown to its full size, and has as many cell layers as when fully ripe. The outer layer has become thick-walled and is almost empty of protoplasm.

The primary nucleus of the ascus now undergoes three successive divisions, giving rise to two, four, and finally to eight nuclei (figs. 9, 10, 11), each of which becomes the nucleus of a spore (figs. 17, 18).

The process of spore formation in *Erysiphe aggregata* resembles in every way that described by Harper (1905) in detail for *Erysiphe communis* and *Phyllactinia corylea* and by Sands (1907) for *Microsphaera alni.*

In the process of the cutting out of spores, the eight nuclei formed by the third division retain their asters; from these there continue to grow out long, fine threads which become more numerous. From the beginning the asters are turned toward the periphery of the ascus. The nuclei of the ascus become beaked and the rays then begin to curve back about the nucleus. This folding back continues until the majority of the fibers lie in one plane. These fibers form rather a hemispherical covering over the beaked nucleus.

The lateral fusion of the rays begins early, even before the sporeplasm is delimited. This has been pointed out by Harper. After the fibers have completely fused, so that the sporeplasm is actually separated from the epiplasm, the beak of the nucleus is slowly drawn in (fig.15), and the nucleus, in a resting condition (fig. 14), again lies in the center of the mass. Between the spore membrane and surrounding protoplasm, a space appears in which the spore wall is finally deposited. With the ripening of the spores, the perithecium reaches its maturity.

The present study on *Erysiphe aggregata* agrees with most of the findings of other investigators for other species of the Erysiphaceae, which they have studied.

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EXPLANATION OF PLATES

All figures were drawn with the Abbe camera lucida. Figs. 3, 4, 5, 12, 13, 14, and 15 are magnified approximately X 1400; figs. 1 and 2 are magnified X 1200; figs. 6, 8, 9, 10, 11, 16, 17, 18 are approximately X 950 and fig. 7 is magnified X 400.

PLATE III

FIG. 1. Elongate, uninucleate mycelium.

FIG. 2. Ascogonium with five cells surrounded by hyphae or beginnings of perithecial envelope.

FIGS. 3, 4. Ascogenous hyphae showing binucleate penultimate cell which will become the ascus.

FIG. 5. See Plate IV.

FIG. 6. Section through a young perithecium showing no definite differentiation of layers. "Nurse cells" to the inside are binucleate.

FIG. 7. Section through older perithecium containing young asci. The primary ascus nucleus visible in the center of the ascus. "Nurse cells" are still binucleate.

FIG. 8. Young ascus containing the primary ascus nucleus centrally located.

FIG. 9. Young ascus containing two nuclei.

FIG. 10. Ascus containing four nuclei.

FIG. 11. Ascus containing eight nuclei, six of which are visible, the other two nuclei are in another section.

PLATE IV

FIG. 5. Ascogenous hypha showing binucleate penultimate cell which will become the ascus.

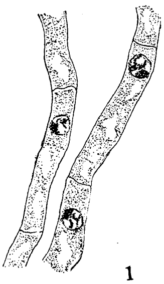
FIGS. 12, 13. Ascospores delimiting. Nucleus distinctly beaked. Shows plasma membrane drawn in.

FIG. 14. Ascospore completely delimited showing the nucleus in a resting condition.

FIG. 15. Stage in drawing in of nuclear beak. Spore formation complete.

FIG. 16. Mature ascus showing spore formation.

FIGS. 17, 18. Mature asci with mature spores.



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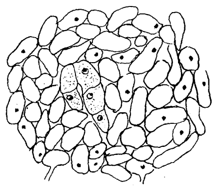

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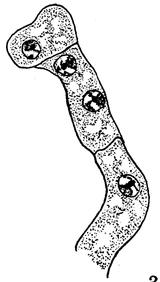

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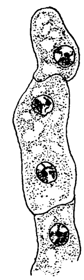

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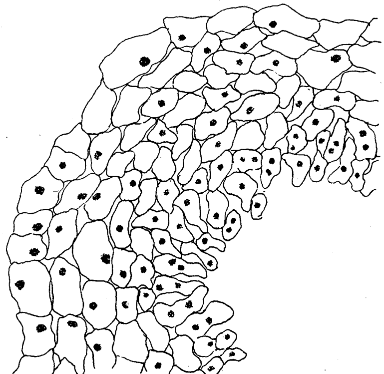

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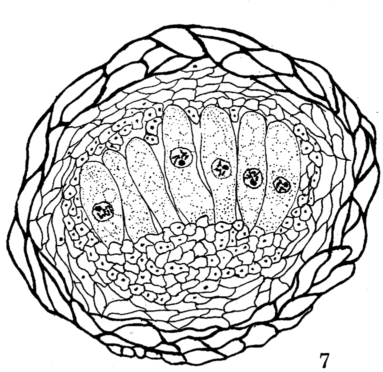

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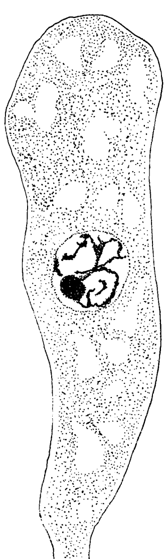

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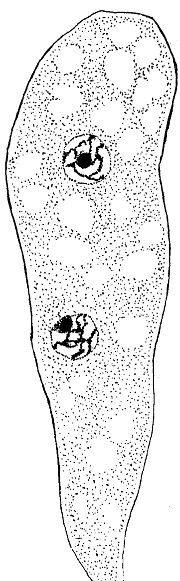

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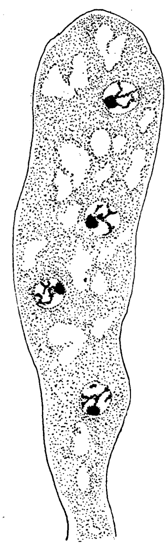

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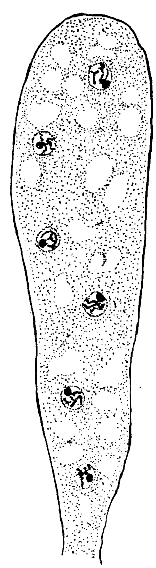

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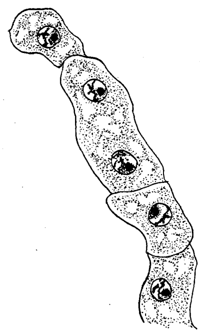

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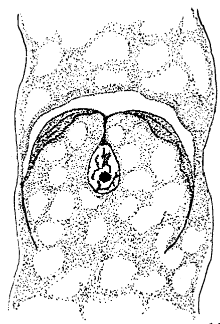

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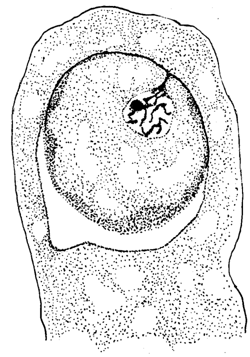

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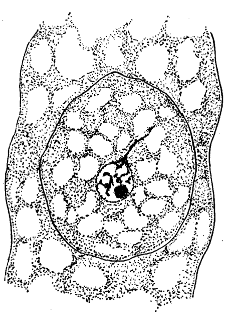

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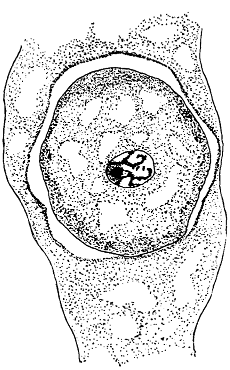

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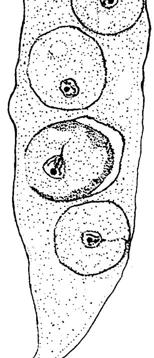

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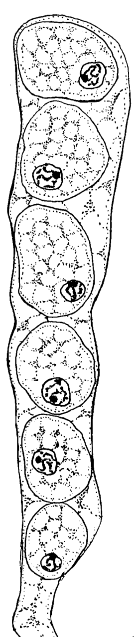

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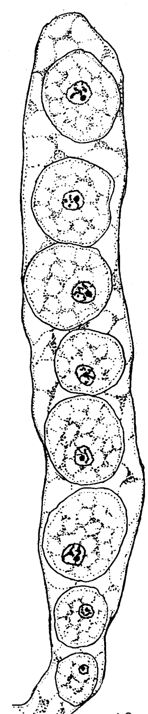


18

NOTES ON PARASITIC FUNGI IN WISCONSIN. XVIII.

J. J. DAVIS

Reference has been made to the occurrence of Phyllachora on *Andropogon furcatus* in Wisconsin which had been seen in an immature condition only. A specimen on old rusted leaves of *Andropogon furcatus* from Avoca May 28, 1929 indicates that it is not morphologically distinct from *Phyllachora graminis* (Pers.) Fckl. The asci are 65-80 × 8-10μ and the spores 7-11 × 7μ. It is sometimes abundant on this host.

For the parasite described under the binomial *Gloeosporium balsameum* in "Notes" VII, p. 409, the genus Rhabdogloeopsis has been proposed by Petrak (*Ann. Mycol.* 23: 52). Branching of the conidiophores and more than one conidium at the apex were not shown in the figure or indicated in the description. This was searched for in the type locality in 1929 without success, but it was found at Bailey's Harbor.

A collection on leaves of *Aquilegia canadensis* from Sturgeon Bay, July 26, 1929 shows reddish brown spots 1½-2 cm. long in the direction of the veins, about one-half as wide, paler on the lower surface; pycnidia succineous, globose, more or less depressed, 100-150μ in diameter; sporules hyaline, straight 4-7× 1½-3μ. This is probably a microconidial or immature state of *Ascochyta aquilegiae* (Rabh.) Hoehn. which is a member of the group on Actaea, Thalictrum and Clematis referred to in "Notes" V, p. 298. The description of *Phyllosticta aquilegiae* Tehon & Daniels (*Mycologia* 17: 241) suggests that it may be a further development of the same parasite.

In the *Bulletin of the Torrey Botanical Club* 27: 572 (1900), *Phyllosticta similispora* Ell. & Davis was published as a new species based upon material on *Solidago rigida* from Wisconsin. In *Annales Mycologici* 10: 312 (1912), *Leptothyrium tumidulum* Sacc. n. sp. was published based upon material on *Solidago rigida* sent from Ontario by Dearness. The former was distributed in *Fungi Columbiani* Shear *1446,* the latter in *Fungi Columbiani* Bartholomew *4637*. Examination of authentic material indicates that these are conspecific. The pycnidia usually develop on the upper leaf surface and are prominent, varying in shape from plano-convex to hemispherical to obtusely conical. When they develop on the lower surface however, as they sometimes do, they push into the mesophyll and are globose. The hymenium seems to be continuous except for the ostiole. The specific name, similispora, was suggested by the similarity of the sporules to those of *Phyllosticta sphaeropsispora* Ell. & Ev. on *Solidago confinis* in southern California which is said to differ in the character of the spots. A closely allied form is *Phyllosticta astericola* Ell. & Ev. which occurs in Wisconsin on *Aster umbellatus* developing similar pycnidia and sporules.

For several years *Cylindrosporium tradescantiae* Ell. & Kell. has been labeled *Septoria tradescantiae* (E. & K.) n. comb. in the herbarium because the sporules are formed in definite pycnidia.

A specimen on Aster (paniculatus?) collected May 18, 1929 bears sporules some of which exceed 80μ in length but it is referred to *Septoria astericola* Ell. & Ev. because they are but about 1μ in diameter. This species develops in spring (May, June), *S. atropurpurea* Pk. in summer.

Septoria nolitangeris Gerard usually develops in Wisconsin on immarginate spots but slightly paler than the leaf. It may be that the spots become typical later. It occurs on cotyledons as well as on foliage leaves. Immature perithecia are found in some of the specimens. The character of the spots probably depends upon the amount of light received.

In the *Journal of Mycology* **6**: 34 (1890) Ellis & Halstead described *Gloeosporium cladosporioides* n.s. on *Hypericum mutilum* from a New Jersey collection. In this description is the sentence "Hyphae fasciculate, continuous, toothed above, hyaline becoming brown". At that time the word hyphae, contraction of fertile hyphae, was used to designate what are now called conidiophores. The description indicates that the parasite differs from Gloeosporium as that genus is now understood. Specimens of this were issued in Ellis & Everhart *North American Fungi 2438.* In *Some Fungi from Alabama (Bulletin of Cornell University* (Science) 3: 39 (1897) Atkinson described *Cladosporium gloeosporioides* n. sp. based on a collection made by himself on *Ascyrum stans* and one on "*Hypericum mutilum,* Sept. 1891 (Duggar)". Following the description is the statement "Very different from Gloeosporium cladosporioides". In *Bulletin of the Alabama Experiment Station* No. 80, p. 160 Underwood & Earle recorded *Colletotrichum cladosporioides* (E. & E.) Atkinson and cited Lee [county], 9, 1891 (Duggar). In the list of Fungi contributed by Earle to Charles Mohr's *Plant Life of Alabama (Contributions from the U. S. National Herbarium* 6, (1901) *Cladosporium gloeosporioides* Atkinson is recorded with references to the same collections that were cited by Atkinson in his description of the species. This record is on p. 238 and on p. 250 appears the entry *Colletotrichum cladosporioides* (E. & E.) Atkinson, Ala. Bull. 160 "*On Hypericum mutilum,* Lee county, September, 1891 (Duggar)". Atkinson apparently made no publication himself of this binomial. The inference to be drawn is that he later considered his *Cladosporium gloeosporioides* to be a Colletotrichum. For the insertion of (E. & E.) I cannot account unless it was an error for Ell. & Hals. and that he had concluded that the *Gloeosporium cladosporioides* and the Colletotrichum were conspecific.

In 1912 collections were made at Wisconsin Rapids (Peltier) and Madison on *Hypericum virginicum* that were recorded in the Wisconsin "Notes" I, pp. 91-2, under the name *Cladosporium gloeosporioides* Atk. with the suggestion that it might be conspecific with *Gloeosporium cladosporioides* Ell. & Hals. Specimens from Madison were issued in Sydow *Fungi exotici exsiccati 99* with the Ellis & Halstead binomial given as a synonym on the label. Specimens from London, Canada, collected by Dearness were issued in Bartholomew *Fungi Columbiani 2416* under the same name.

That the hyaline, continuous conidia are not characters of Cladosporium as that genus is now understood is evident. Why it was referred to Colletotrichum by Atkinson was a puzzle until it was noticed that in some of the tufts there were conidia on short, hyaline, delicate basidia as well as on the long dark conidiophores. As the conidia usually fall from the conidiophores in water such a mount might readily be taken for Colletotrichum. In the Wisconsin specimens the conidiophores are usually straight and rigid and resemble the setae of Colletotrichum. It does not seem likely that Atkinson intended to refer this to *Colletotrichum gloeosporioides* Penzig. In addition to the collections referred to above are one each from Cameron and Dexterville, Wisconsin, but it is perhaps better to wait until more material is available before assigning this parasite to the polymorphous genus Cercospora. *Cercospora hyperici* Tehon & Daniels [*Mycologia* **19** : 127-8, (1927)] on *Hypericum adpressum* in Illinois I have not seen, but the shorter conidiophores and longer, sometimes septate, conidia appear to separate it.

In *Annals of the Missouri Botanical Garden* **16:** 42 Miss Lieneman called attention to the fact that *Cercospora molluginis* Davis "Notes" X p. 285 is antedated by *C. molluginis* Hals. and proposed *Cerecospora molluginicola* nom. nov. for the former. The variation in conidia in this genus is such as to make it doubtful that they are distinct.

The parasite found on nursery plants of *Amorpha fruticosa* in Iowa and recorded and figured in *The Fungi of Iowa Parasitic on Plants,* No. 206, as *Cylindrosporium passaloroides* (Wint.) comb. nov. seems to be quite different from *Cercospora passaloroides* Wint., which is a true Cercospora as clearly indicated in Winter's description and shown by Ellis & Everhart, *North American Fungi 1999,* Bartholomew *Fungi Columbiani 3512* and 13 Wisconsin specimens in the herbarium of the University of Wisconsin. The hyphae from which the conidiophores of the Cercospora spring are sometimes, in part, superficial.

Cercospora viticola (Ces.) Sacc. has been connected by Higgins with an ascigerous state which he has described and named *Mycosphaerella personata* n. sp. (*Am. Journ. Bot.* **16:** 295.)

Of a collection of a parasite that occurs on *Halenia deflexa* in Wisconsin and that has been referred to *Cercospora gentianicola* Ell. & Ev. the following notes were made: spots indefinite or none; conidiophores amphigenous, subfuliginous, borne on black stromatic tubercles, $7–20 \times 3–4\mu$; conidia hyaline, flagelliform, straight or curved, 2–4 septate, $50–90 \times 3–4\frac{1}{2}\mu$. On the upper surface of the leaves are what appear to be young perithecia which are black, somewhat dendritic in distribution, giving an appearance that reminds one of Asteroma.

From a collection on leaves of *Cephalanthus occidentalis* made on the bottom lands along the Wisconsin river Oct. 2, 1929 the following notes were made: Spots angular, limited by the veinlets becoming confluent, immarginate, variable in size, reddish brown above, the red tint lacking below; conidiophores amphigenous but more numerous above, fasciculate usually from a black tubercular base, dark olivaceous black by reflected light, continuous or 1–3 septate, straight, geniculate or somewhat undulate, 23–40 × 3–4μ; conidia olivaceous, cylindrical but tapering at base, 1–6 septate, 14–57 × 3½–5μ. The tufts are not numerous and are much scattered. Catenulation of conidia was not observed. A specimen from Kenosha county Oct. 4, 1909 labeled *Cercospora cephalanthi* E. & K. with the notation "spots different" is similar but with a few definite, orbicular, marginate spots and others that seem to be intermediate. Another specimen, same locality and date but probably from a different station shows only typical spots. In a collection from near Oakwood the spots are smaller, sordid and lacerate. It would seem that the reaction of the host to this parasite varies under different conditions. Of the Texan parasite described by Heald under the binomial *Ramularia cephalanthi* (E. & K.) Heald (*Bureau of Plant Industry Bulletin* 226, p. 61) I have not seen a specimen.

In "Notes" VII, p. 206 *Uromyces hyperici-frondosi* (Schw.) Arth. was reported on *Hypericum canadense* but the host appears to be *H. majus* instead.

The inclusion of Wisconsin in the range of *Puccinia windsoriae* in *North American Flora* was an error as I am informed by Dr. Arthur.

Darker has shown that *Pucciniastrum arcticum* (Lagh.) Tranz. and *P. americanum* (Farl.) Arth. have their aecial stage on *Picea canadensis* and that *Peridermium ingenuum* Arth. is that stage (*Journ. Arnold Arboretum* 10:156 *et seq.*). To which of the raspberry rusts the *Peridermium* collected in Wisconsin belongs is not known. The situation is like that of *Peridermium balsameum* Pk. and *Uredinopsis* on ferns and Caeoma on *Larix laricina* and *Melampsora bigelowii* Thuem. and *M. medusae* Thuem. Such conditions suggest very close relationships.

In 1932 de Schweinitz published a description of a rust on Andropogon which he named *Puccinia andropogi,* usually corrected to *andropogonis.* Ten years earlier he recorded *Caeoma (Aecidium) pentastemonis* on Pentstemon. In 1899 Arthur found that this is an aecial stage of the rust on Andropogon and other Scrophulariaceous hosts are known. In 1872 Peck published a description of *Aecidium mariae–wilsoni* on Viola and in 1878 von Thuemen described *Puccinia ellisiana* on Andropogon. These were found to be connected by Arthur in 1912. This has not been recognized in Wisconsin. In 1873 *Aecidium pustulatum* Curtis on Comandra was described by Peck. In 1903 Arthur found this to be connected with a rust on Andropogon and proposed the name *Puccinia pustulata* Curt. In *N. A. Flora* this was considered to be a race of *P. andropogonis*. In 1884 Ellis & Kellerman described *Aecidium ceanothi* on *Ceanothus* from Kansas. In 1909 Arthur succeeded in infecting *Ceanothus americanus* with germinating telia on *Andropogon Hallii* from Nebraska. It is of interest that sowing of the teliospores on *Baptisia tinctoria, Psoralea Onobrychis* and *Zanthoxylum americanum* among other hosts brought no result. The Aecidium on *Ceanothus ovatus* has been collected in northwestern Wisconsin but the stage on Andropogon has not been recognized. This was given the name *Puccinia ceanothi* by Arthur.

In addition to these *Puccinia Kaernbachii* (P. Henn.) Arth. occurs in Florida but its aecial connection is not known. *Uromyces andropogonis* Tracy *(U. pedatatus* (Schw.) J. L. Sheldon) having aecia on Viola and the later stages on Andropogon occurs in the United States and is thought to be closely related to *Puccinia ellisiana* Thuem. In *North American Flora* 7 proposed species of Aecidium on Leguminosae were united under the binomial *Aecidium onobrychidis* Burr. Of these two are known to occur in Wisconsin. One of them, *Aecidium falcatae* Arth., has been connected with rust of *Andropogon furcatus* as recorded in "Notes" XIV & XV. In 1929 *Andropogon furcatus* was infected in the greenhouse from the other, *Aecidium lupini* Pk. on *Lupinus perennis.* This connection has not been previously recorded. In 1926 connection of rust on *Andropogon furcatus* and *Aecidium xanthoxyli* Pk. was made in the greenhouse and was recorded in "Notes" XV. This was thought to be similar to the Comandra-Andropogon form. In 1927 rusted Andropogon from one source was found to infect *Polygala Senega* in the field but not that from another locality. Germination tests were not made before placing the rusted *Andropogon* plants as that was done early in the season. With the *Aecidium* *polygalinum* Pk. thus produced *Andropogon furcatus* was infected in the greenhouse as recorded in "Notes" XVI.

It is evident that much is yet to be learned about the rusts of Andropogon.

ADDITIONAL HOSTS

Plasmopara pygmaea (Ung.) Schroet.

Conidia and young oospores on *Anemone virginiana.* Blue River.

Peronospora calotheca DBy.

On *Galium concinnum.* Sauk City. (Seymour, Jones & Davis).

A collection on *Potentilla arguta* bearing conidia only was preserved and referred to *Sphaerotheca humuli* (DC.) Burr. Perithecia have not been found on this host. A collection on *Shepherdia canadensis* from Bailey's Harbor is presumably of this species but only conidia are present.

Microsphaera alni (Wallr.) Wint.

On *Viburnum Opulus.* Fish Creek. In this collection the perithecia are small and scattered and the appendages short.

Melilotus alba should be recorded as a host of *Pseudopeziza medicaginis* (Lib.) Sacc. in Wisconsin.

A collection of the parasite recorded in "Notes" XVII, p. 300 as *Cercospora junci* n. sp. was made at Bailey's Harbor on *Juncus brachycephalus* Aug. 21, 1929 but mature conidia were not found on the dried material. The basal tubercles extend deeper into the leaf than in the type.

Uromyces acuminatus magnatus (Arth.)

Aecia on *Maianthemum canadense* collected at Lampson by Dr. Fassett have been so determined.

Uromyces hyperici-frondosi (Schw.) Arth.

Uredinia and telia on *Hypericum prolificum.* Bailey's Harbor.

Puccinia patruelis Arth.

Aecidium on *Lactuca sativa* (cult.) Madison. (A. C. Foster).

Puccinia bolleyana Sacc.

Uredinia and a few telia on *Carex Bebbii.* Jacksonport.

Satureja vulgaris should be included with the hosts of *Puccinia menthae* Pers. in Wisconsin.

Pucciniastrum pustulatum (Pers.) Diet.
On *Epilobium densum.* Menomonie. (Bachman & Patrick).

Calyptospora goeppertiana Kuehn is not common in Wisconsin. It was found at White Lake on *Vaccinium canadense* in 1921 and at Ellison Bay on *V. pennsylvanicum* in 1929.

Adjoining *Pteris aquilina* bearing *Sclerotium deciduum* Davis near Sturgeon Bay were single plants of *Trientalis americana, Fragaria virginiana* and *Rubus allegheniensis* infected apparently by the same parasite. Only the Trientalis bore typical sclerotia. The presclerotial stage was also found on Trientalis at Ellison Bay.

Additional Species

not previously reported as occuring in Wisconsin.

Taphrina aurea (Pers.) Fr.
This was collected at Terry Andrae Park on the shore of lake Michigan south of Sheboygan on *Populus nigra italica.* The collection was made July 17th and the material was overmature the spots having lost their yellow color and most, but not all, of the asci had discharged.

A scanty collection on *Iris lacustris* from Fish Creek in which the pycnidia are mostly immature or imperfectly developed is referred to *Phyllosticta cruenta pallidior* Pk. The sporules are about $10 \times 8\text{–}10\mu$.

A collection having the appearance of *Phyllosticta punctata* Ell. & Dearn. on *Viburnum Opulus* was made at Fish Creek but no sporules were found in the pycnidia. This is quite similar to *Phyllosticta decidua* Ell. & Kell. which occurs on shrubs as well as herbs and which often fails to develop sporules.

Ascochyta imperfecta Pk. on *Medicago sativa* appears not to have been recorded in the Wisconsin lists. In 1929 it was observed in a field of alfalfa and sweet clover mixed attacking the alfalfa only.

On July 10, 1929 a collection of *Peronospora linariae* Fckl. on *Linaria canadensis* was made at Arena. On the dead stems are pale spots in which are pycnidia with black rather firm thick walls and broadly conical ostioles. These pycnidia contain hyaline, lax, filiform scolecospores 30–50 × ½–1μ. The appearance suggests that the death of the host interfered with the normal development of the sporules. Perhaps this bears relation to *Septoria cymbalariae* Sacc. & Speg.

Septoria pentstemonicola Ell. & Ev.
On *Pentstemon gracilis*. Mazomanie. Sporules 40–70 × 3μ.

Cercospora dulcamarae (Pk.) E. & E.
On *Solanum Dulcamara*. Ellison Bay. In this collection the spots are dark blue on both surfaces reminding one of a wood stain.

Puccinia investita Schw.
Aecia and telia on *Gnaphalium decurrens*. Mellon. (Fassett).

Pucciniastrum galii (Lk.) Ed. Fisch.
Uredo on *Galium triflorum*. Ellison Bay. This rust appears to be very rare east of the Rocky Mountains.

University of Wisconsin Herbarium
April 1930

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. XII.

POLYPODIACEAE

EDITH W. BREAKEY AND RUTH I. WALKER

The distributional maps of this report were compiled from specimens in the herbaria of the University of Wisconsin, of the Milwaukee Public Museum, of the Field Museum (with the exception of *Athyrium* and *Thelypteris*), and of Lawrence College.

POLYPODIUM (Tourn.) L.

P. VIRGINIANUM L.; Fernald, Rhodora 24: 141, 1922. *P. vulgare* of Am. Auth. in part, not L. Common Polypody (Fig. 1). Distribution general throughout Wisconsin; most abundant on shaded ledges of rocks and woodland banks.

PTERIDIUM Raf.

P. LATIUSCULUM (Desv.) Maxon, Am. Fern Journ. 9: 43, 1919. *Pteris aquilina* of Gray's Manual, ed. 7. Common Brake. (Fig. 2.) Distribution general except for sandy areas of central Wisconsin as indicated on the distributional map and determined from figure 3, page 11 of Wisconsin Statistical Atlas 1926-27. Bulletin 90. Found in woods, often hillsides and pastures. Frequent on burnt and cut over areas.

ADIANTUM (Tourn.) L.

A. PEDATUM L. Common Maidenhair. (Fig. 3.) Generally distributed in moist shady woods with exception of sandy regions as indicated on distributional map, figure 2.

CHEILANTHES Sw.

C. FEEI Moore. Slender Lip Fern. (Fig. 4.) In dense tufts in dry crevices of rocks and cliffs. For the most part confined to lime and sandstone areas adjacent to the Wisconsin and Mississippi rivers (see fig. 5).

C. LANOSA (Michx.) Watt. Hairy Lip Fern. (Fig. 4.) Collected at St. Croix Falls.

PELLAEA Link.

P. GLABELLA Mett. ex Kuhn; Butters, Am. Fern Journ. 7: 77-87, 1917. *P. atropurpurea* of Gray's Manual, ed. 7, in part. (Fig. 5). Mostly southern. Found on dry rocky ledges of limestone, rarely on calcareous sandstone underlying such ledges. Areas of limestone are indicated on the map. (For Pallaea in fig. 5 read Pellaea.)

CRYPTOGRAMMA R. Br.

C. STELLERI (Gmel.) Prantl. Slender Cliff Brake. (Fig. 6). Confined to damp moist shaded crevices of limestone areas.

ASPLENIUM L.

A. VIRIDE Huds. Green Spleenwort. (Fig. 7). Collected but once in Wisconsin, on shaded limestone of Washington Island, Door County.

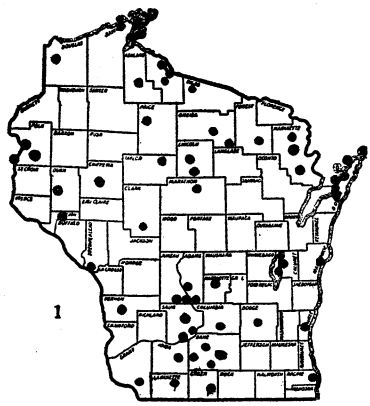
A. TRICHOMANES L. Maidenhair Spleenwort. (Fig. 8). Rocky ledges and talus of gabbro cliffs in northern Wisconsin; on limestone in Door Co.; on sandstone at the Wisconsin Dells; and on quartzite at Devils Lake.

A. PLATYNEURON (L.) Oakes. Ebony Spleenwort. (Fig 7). Rare in Wisconsin. Found in thinly wooded rocky slopes in the driftless area.

ATHYRIUM Roth ex Mertens

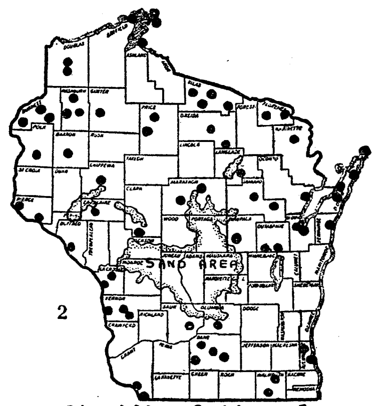
The members of this genus occurring in Wisconsin may be distinguished as follows:

a. Indusium straight or slightly curved. *b*
  b. Fronds pinnate .... *A. angustifolium.*
  b. Fronds pinnatifid .... *A. acrostichoides.*
a. Indusium horseshoe-shaped or curved at one end. *c*
  c. Fronds dimorphic. *d*
    d. Longest pinnae of the fertile frond 5–12 cm. long, pinnules 4–12 mm. long, simple .... *A. angustum* f. *typicum.*
    d. Longest pinnae of fertile front 1–2 dm. long, pinnules 12–25 mm. long, pinnatifid .... *A. angustum* var. *elatius.*
  c. Fronds not dimorphic .... *A. angustum* var. *rubellum.*



1

Polypodium virginianum



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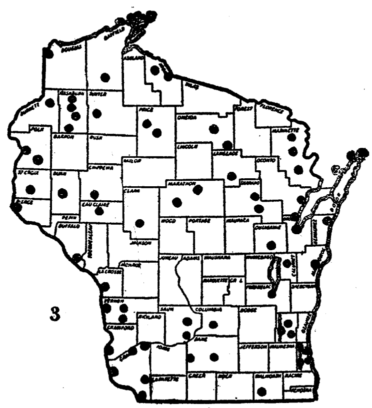
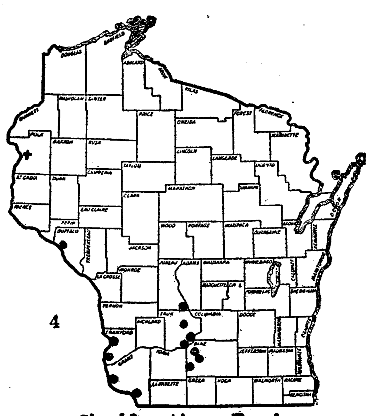
Pteridium latiusculum



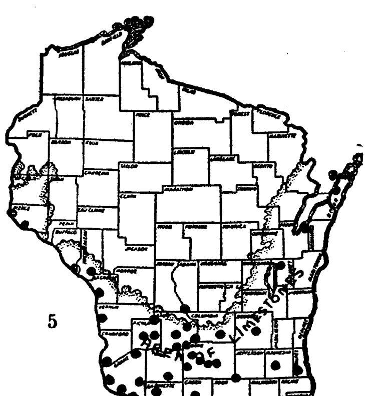
3

Adiantum pedatum



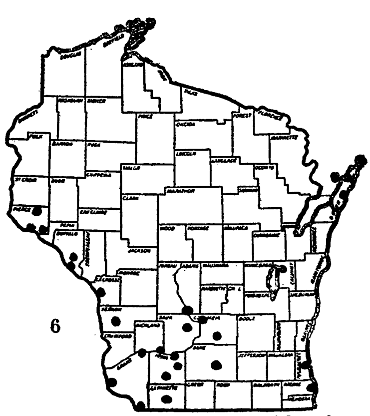
4

• **Cheilanthes Feei**
+ **Cheilanthes lanosa**



5

Pallaea glabella



6

Cryptogramma Stelleri

A. ACROSTICHOIDES Sw. Diels. Nat. Pfl. 1, pt. 2, 223, 1899. *Asplenium acrostichoides* of Gray's Manual, ed 7. Silvery Spleenwort. (Fig. 9). Occasionally found in rich, moist, shady woods.

A. ANGUSTIFOLIUM (Michx.) Milde, Bot. Zeit. 24: 376, 1866. *Asplenium angustifolium* of Gray's Manual, ed. 7. Narrow-leaved Spleenwort. (Fig. 9). Occasionally found in rich woods.

A. ANGUSTUM (Wild.) Presl, f. TYPICUM, Butters, Rhodora 19: 191, 1917. *Asplenium Filix-femina,* in part, of Gray's Manual, ed. 7. Upland Lady Fern. (Fig. 10). Not common. Forms intermediate between *A. angustum,* f. *typicum* and *A. Angustum,* var. *elatius* are indicated by crosses on the map.

A. ANGUSTUM (Willd.) Presl, var. ELATIUS (Link) Butters. Rhodora 19: 191, 1917. (Fig. 11). Distribution general throughout the state except for sandy regions as indicated in map, fig. 2. Found in swamps or in woods.

A. ANGUSTUM (Willd.) Presl, var. RUBELLUM (Gilbert) Butters. Rhodora 19: 193, 1917. (Fig. 12). Forms intermediate between *A. angustum,* var. *elatius* and *A. angustum,* var. *rubellum* are indicated by crosses on the map. Generally distributed throughout the state except for sandy regions as indicated in map, fig. 2. Found in swamps, or in rich moist or sandy woods.

CAMPTOSORUS Link.

C. RHIZOPHYLLUS (L.) Link. Walking Fern. (Fig. 13). Distribution generally southward on shaded wooded hillsides, on moss covered limestone ledges or other rocks (see fig. 5).

POLYSTICHUM Roth.

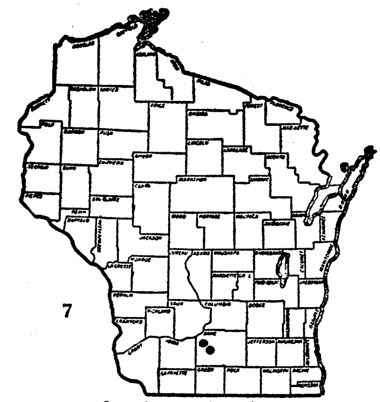
P. ACROSTICHOIDES (Michx) Schott. Christmas Fern. (Fig. 14). Collected in rocky woods at Racine.

P. BRAUNII (Spenner) Fee, var. PURSHII, Fernard, Rhodora 30: 30, 1928. Braun's Holly Fern. (Fig. 14). Found rarely in shady woods and rock slides in northern part of the state.

THELYPTERIS Schmidel.

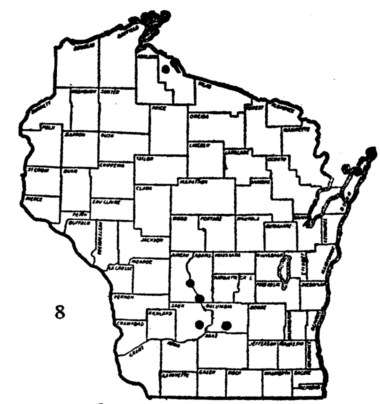
Aspidium in Gray's Manual, ed 7.

T. SPINULOSA (Retz.) Nieuwl. Am. Midland Nat. 1: 226, 1910. Spinulose Shield Fern. (Fig. 15). In woods, almost anywhere except in sandy regions as indicated on map 2.



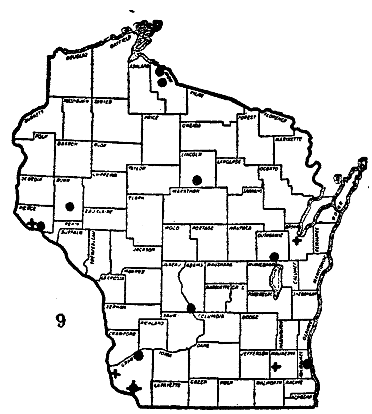
7

+ Asplenium viride
• Asplenium platyneuron



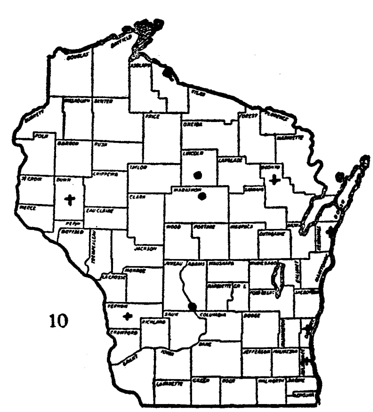
8

Asplenium Trichomanes



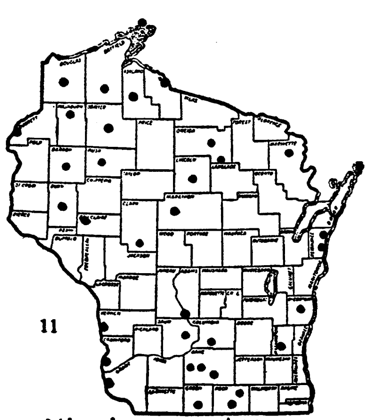
9

• Athyrium acrostichoides
+ Athyrium angustifolium



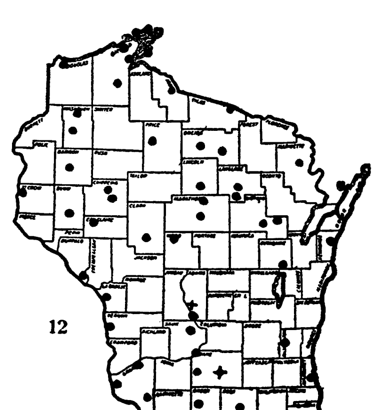
10

Athyrium angustum



11

Athyrium angustum, var. elatius



12

Athyrium angustum, var. rubellum

T. SPINULOSA (Retz.) Nieuwl., var. INTERMEDIA (Muhl.) Weath. Rhodora 21: 178, 1919. (Fig. 16). Generally distributed but apparently absent from The Driftless Area. Found in deep damp caves, shaded ledges of rocks and moist woods.

According to Dr. F. K. Butters (in litt.) *T. intermedia* may be considered a distinct species, with spores averaging 25.5 × 36.2μ while in *T. spinulosa* and all its other varieties the spores average over 31 × 46μ. Measurements of twelve spores from each of 17 specimens of *T. spinulosa* in the Herbarium of the University of Wisconsin average 29.9×45.9μ. Spore measurements of twelve spores from each of 33 specimens of *T. spinulosa* var. *intermedia* average 26.30 × 37.4μ. Spore measurements of twelve spores from each of 4 specimens of *T. spinulosa* var. *americana* average 30.8 × 49.9μ.

T. SPINULOSA (Muell.) Nieuwl., var. AMERICANA (Fisch.) Weath. Rhodora 21: 178, 1919 (Fig. 19). *Aspidium spinulosum,* var. *dilatum,* f. *anadenium* of Gray's Manual, ed. 7. Not common. Found in shady woods.

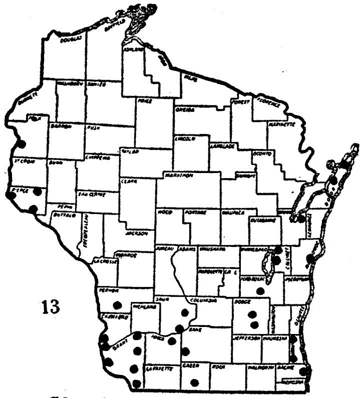
T. PALUSTRIS (Salisb.) Schott, var. PUBESCENS (Lawson) Fernald. Rhodora 31: 34, 1929. *Aspidium Thelypteris* of Gray's Manual, ed. 7. Marsh Fern. (Fig. 17). Generally distributed but rarely found in The Driftless Area. Most common in swamps, marshes and bogs.

The specimens cited as *Aspidium noveboracense* (L.) Sw. by Dr. Wm. Steil and A. M. Fuller in Am. Fern Journ. 18: 112, 1929, have been examined by the authors and are referred to the following species; *Athyrium acrostichoides, A. angustum,* f. *typicum, A. angustum,* var. *elatius, A. angustum,* var. *rubellum,* and *Thelypteris palustris,* var. *pubescens.*

T. DRYOPTERIS (L.) Slosson, in Rybd. Fl. Rocky Mts., 1044, 1917, *Phegopteris Dryopteris* of Gray's Manual, ed. 7. Oak Fern. (Fig. 18). Distribution general, usually in rocky, wet woods near rivers and lakes.

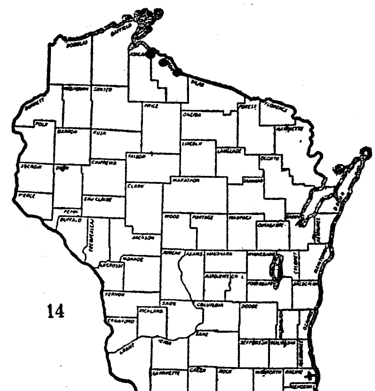
T. FRAGRANS (L.) Nieuwl., var. HOOKERIANA Fernald, Rhodora 25: 3, 1923. *Aspidium fragrans* of Gray's Manual, ed. 7. Fragrant Fern. (Fig. 19). Found only on sandstone cliffs and ledges of Wisconsin Dells, and on dry cliffs and talus slopes in northern and northwestern part of state.

T. CRISTATA L. Nieuwl. Am. Midland Nat. 1: 226, 1910. *Aspidium cristatum* of Gray's Manual, ed. 7. Crested Fern.



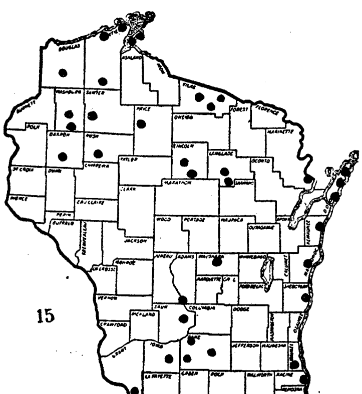
13

Camptosorus rhizophyllus



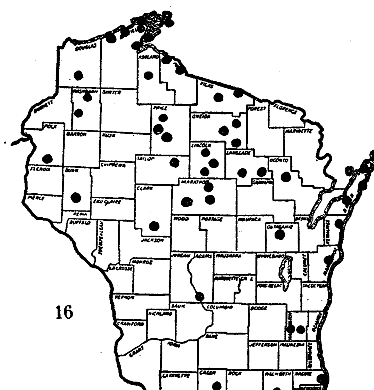
14

\+ Polystichum Braunii, var. Purshii
• Polystichum acrostichoides



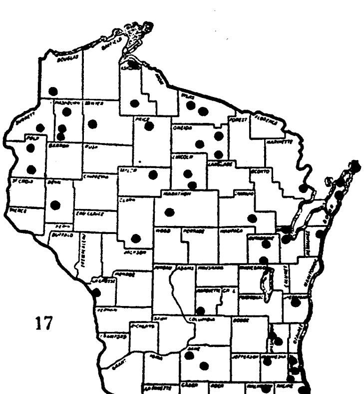
15

Thelypteris spinulosa



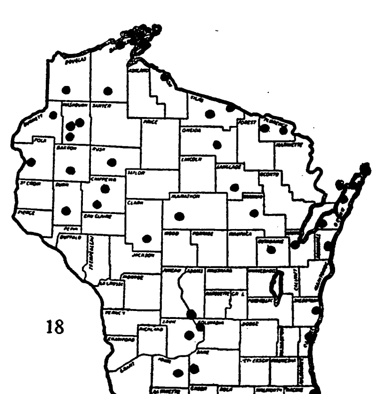
16

Thelypteris spinulosa, var. intermedia



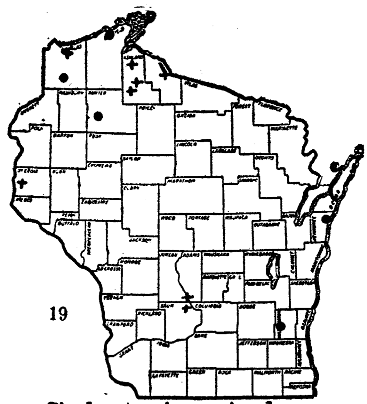
17

Thelypteris palustris, var. pubescens



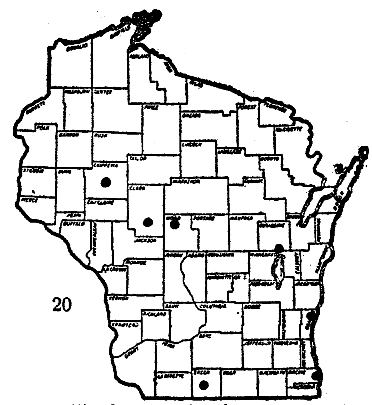
18

Thelypteris Dryopteris



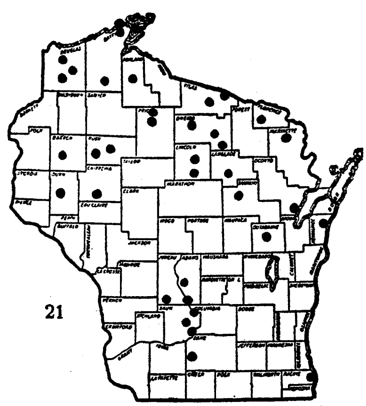
19

• Thelypteris spinulosa, var. Americana
+ Thelypteris fragrans



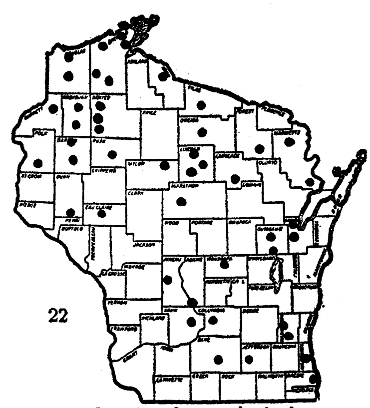
20

Thelypteris hexagonoptera



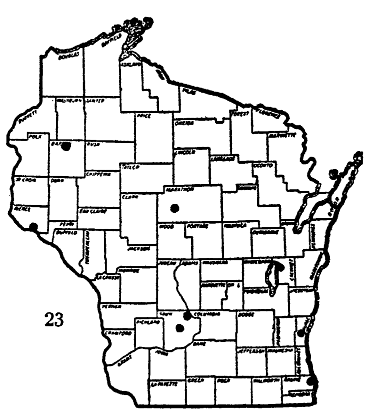
21

Thelypteris Phegopteris



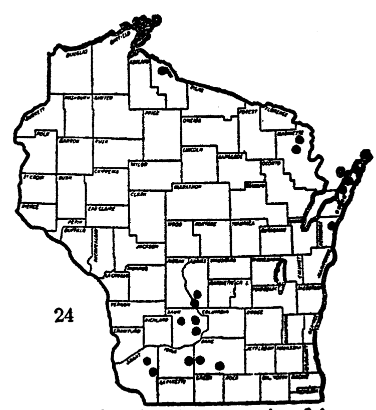
22

Thelypteris cristata



23

Thelypteris Goldiana



24

Thelypteris marginalis

(Fig. 22). Generally distributed except in unglaciated region in damp low ground or in marshes and swamps.

T. GOLDIANA (Hook.) Nieuwl. Am. Midland Nat. 1: 226, 1910. *Aspidium Goldianum* of Gray's Manual, ed. 7. Goldie's Fern. (Fig. 23). Not common.

T. MARGINALIS (L.) Nieuwl. Am. Midland Nat. 1: 226, 1910. *Aspidium marginale* of Gray's Manual, ed. 7. Marginal Shield Fern or Evergreen Wood Fern. (Fig. 24). Rocky ledges and hillsides in unglaciated area, also northward and north eastward.

T. HEXAGONOPTERA (Michx.) Weath., Rhodora 21: 179, 1919. *Phegopteris hexagonoptera* of Gray's Manual, ed. 7. Broad Beech Fern. (Fig. 20). Occasionally collected in dry open woods.

T. PHEGOPTERIS (L.) Slosson, in Rybd. Gl. Rocky Mts., 1043, 1917. *Phegopteris polypodioides* of Gray's Manual, ed. 7. Long Beech Fern. (Fig. 21). Distribution northward and southward in central eastern portion of state similar to that of *T. Dryopteris* (fig. 18). Found on moist shady banks of ravines and in deep woods.

WOODSIA R. Br.

W. CATHCARTIANA Robinson. Cathcart's Woodsia (Fig. 27). Dells of St. Croix River.

W. ILVENSIS R. Br. Rusty Woodsia. (Fig. 25). Distribution general. Found on rocky ledges and cliffs.

W. OBTUSA (Spreng.) Torr. Blunt-Lobed Woodsia. (Fig. 26). Not common. Distribution limited to rocky limestone areas or quartzite rock of Devil's Lake.

PTERETIS Raf.

P. NODULOSA (Michx.) Nieuwl. Am. Midland Nat. 4: 334, 1916. Onoclea Struthiopteris of Gray's Manual, ed. 7. Ostrich Fern. (Fig. 27). Generally distributed in rich wet woodlands.

CYSTOPTERIS Bernh.

C. BULBIFERA (L). Bernh. Bladder Fern. (Fig. 28). Mostly in limestone and sandstone areas on shaded hillsides and in caves.

C. FRAGILIS (L.) Bernh. Common Bladder Fern. (Fig. 29).

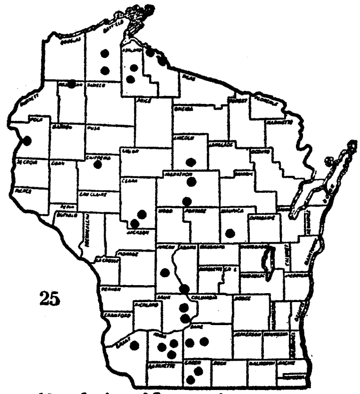
Found for most part on lime and sandstone cliffs and ledges or in moist shaded woods.

ONOCLEA L.

O. SENSIBILIS L. Sensitive Fern. (Fig. 30). Generally distributed in moist meadows or bogs.

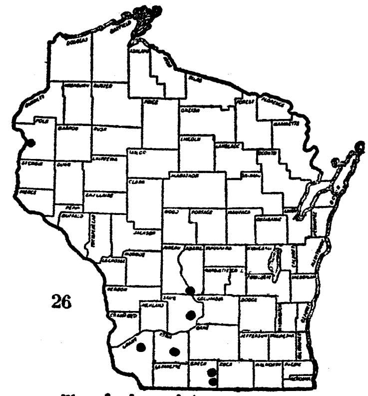
O. SENSIBILIS L., forma OBTUSILOBATA (Torr.) Gilbert, N. Am. Pterid. 18, 1901. (Fig. 30). Collected only at White Lake, Langlade Co.

The authors wish to express their appreciation to Dr. Norman C. Fassett for his suggestions and criticism given in this work.



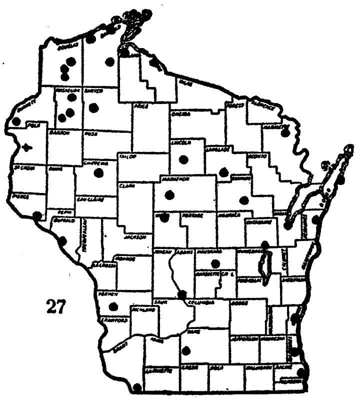
25

Woodsia ilvensis



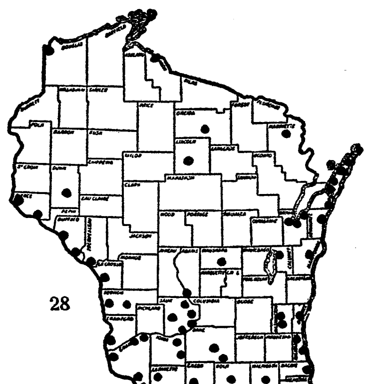
26

Woodsia obtusa



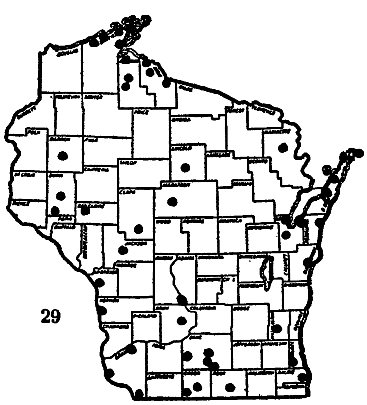
27

+ Woodsia Cathcartiana
• Pteretis nodulosa



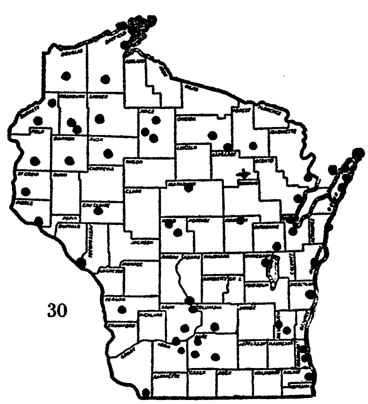
28

Cystopteris bulbifera



29

Cystopteris fragilis



30

• Onoclea sensibilis
+ Onoclea sensibilis, f. obtusilobata

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. XIII. FAGACEAE

DAVID F. COSTELLO

The distribution maps in this report are compiled from field data collected by Mr. L. S. Cheney[1] who traveled and collected in the years 1897 and 1898, and from the herbaria of the University of Wisconsin, of the Milwaukee Public Museum, of Marquette University, and of Mr. S. C. Wadmond of Delavan, Wisconsin. The ranges noted by Mr. Cheney are represented by small dots; additions to these ranges are indicated by crosses. Large dots are used in indicating the range of *Quercus muhlenbergii.*

1. FAGUS

F. GRANDIFOLIA Ehrhart. Beech (Fig. 1). Distribution mostly eastward; frequent in the counties bordering Lake Michigan. Its limits of distribution westward are well marked. Usually frequent to common wherever it is found.

2. QUERCUS

The following key will serve to distinguish the members of this genus occurring in Wisconsin:

a. Leaves not bristle tipped; acorns maturing the first year. *b*
  b. Winter buds downy; cup of fruit fringed; young branches frequently corky ridged .... *Q. macrocarpa*
  b. Winter buds typically smooth or with only slight hairiness at tips and on margins of scales; cup of fruit not fringed. *c*
    c. Buds slightly hairy above middle at times; acorns on peduncles 3–15 cm. long .... *Q. bicolor*
    c. Buds glabrous, bud scales scarious or slightly hairy on margins; acorns sessile or on short peduncles. *d*
      d. Buds broadly ovate, blunt; cup enclosing about ¼ of nut; nuts 18–30 mm. long .... *Q. alba*
      d. Buds conical, sharp pointed; cup enclosing about ½ of nut; nuts 15–20 mm. long .... *Q. muhlenbergii*
a. Leaves bristle tipped; acorns maturing the second year *b*

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[1] See Fassett, Trans. Wis. Acad. Sci., Arts and Let. 25:177, 1930

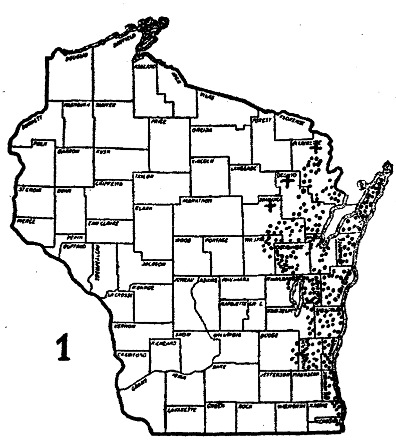
b. Winter buds hairy, 6–12 mm. long, 5-angled or 5-grooved. *Q. velutina*

b. Winter buds glabrous to canescent, smaller than above, seldom angled *c*

c. Buds about 5mm. long, glabrous; cup of fruit saucer-shaped .... *Q. borealis* var. *maxima*

c. Buds about 3mm. long, the slightly puberulent outer scales ciliate on the margins; cup of fruit hemispherical or turbinate .... *Q. ellipsoidalis*

Q. ALBA L. White Oak (Fig. 2). Abundant in all of the counties south of the northern border of Marathon County. It is absent from the northern part of the state, its northern limits almost coinciding with the southern limits of *Picea canadensis* (Mill.) BSP.[2] Cheney states[3] that "The white oak grows in all soils excepting those of a very light sandy nature and the extreme wet marshy soils. It is found associated with red oak, the bur oak, the hickory, the white ash, and in Wisconsin, the yellow birch and the hard maple."



1

Fagus grandifolia

Q. MACROCARPA Michx. Bur Oak. (Fig. 3). Frequent in all counties south of the northern boundary of Marathon County. Northward extensions, where it occurs in considerable abundance, are found in Barron and Polk Counties, and in Oneida County. Its associates include most of the deciduous trees of Wisconsin.

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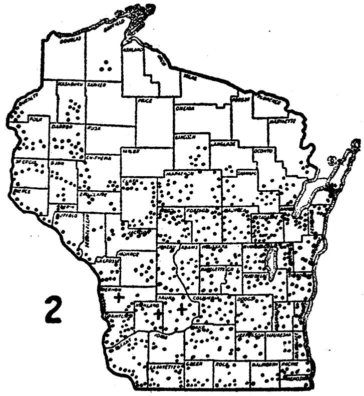
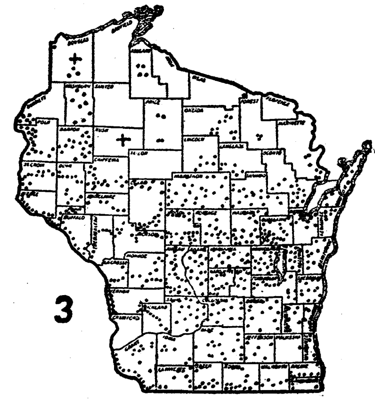
[2] See Fassett, l. c., page 178, fig. 6.

[3] Unpublished data.



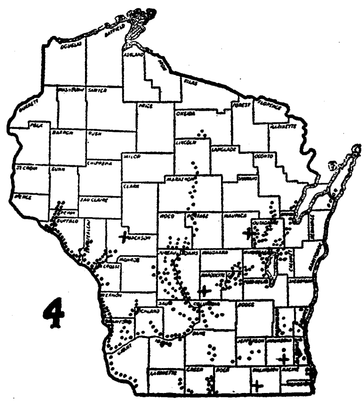
2

Quercus alba



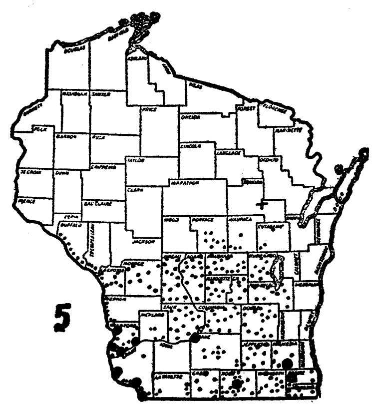
3

Quercus macrocarpa



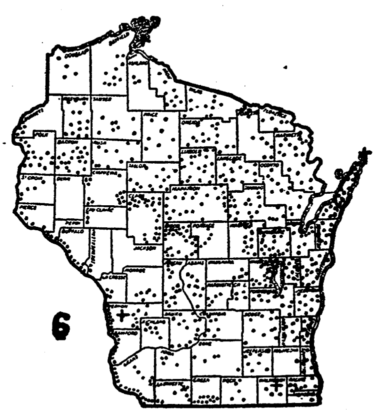
4

Quercus bicolor



5

● Quercus muhlenbergii
⁘ Q. velutina



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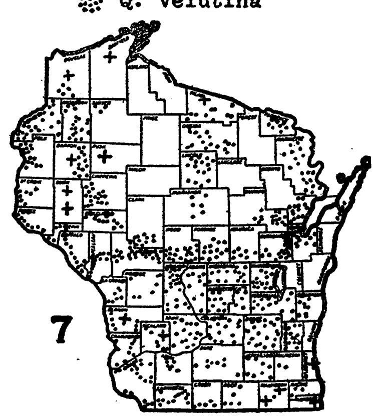
Quercus borealis var. maxima



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Quercus ellipsoidalis

Q. BICOLOR Willd. *(Q. platanoides* Sudworth.) Swamp White Oak. (Fig. 4). Local in its distribution. Occurs in greatest abundance along the Trempealeau River, the Black River, and Wisconsin River, and the Chippewa River. Its northern limit is apparently in Oneida County.

×Q. SCHUETTII Trel., *Proc. Amer. Phl. Soc.* 59:51. 1917. *(Q. bicolor×macrocarpa.)* This cross with characters intermediate between the two species was originally described from Brown County, Wisconsin. It has also been noted near Montreal, Canada, and Rochester, New York. Several specimens, from scattered stations in Wisconsin, with characters resembling the above were examined. Because of the nature of hybrids, and because of the variability of the oaks, the author is unwilling to refer these specimens to *Q. schuettii* without more herbarium material and without further field work.

Q. MUHLENBERGII Engelm. *Trans. Acad. St. Louis* 3:391, 1877. Yellow Oak. (Fig. 5, large dots). Very limited distribution in southern part of Wisconsin. Prefers limestone ridges or gravelly hill sides.

Q. BOREALIS Michx. f., var. MAXIMA (Marsh) Ashe, *Proc. Soc. Amer. For.* 11:90, 1916; Sarg. *Rhodora* 18:48, 1916. *(Q. ruba* of most American authors, not L. *Q. maxima* Ashe, 1-c.; Trel. *Proc. Nat. Acad. Sci.* 20:194, 1924). Red Oak, (Fig. 6). Cheney says, "Within Wisconsin, this is the most widely distributed of the oaks. While it is the oak of the commonest occurrence in the northern third of the state, it does not always reach its largest size there, and is, over most of that territory, of only occasional occurrence. This oak selects as its natural habitat the rich uplands in drift regions; on well-drained borders of streams and swamps, its most constant companions are basswood, white oak, butternut, and hard maple."

Q. ELLIPSOIDALIS Hill.[4] *Bot. Gaz.* 27:204, 1899; Trel. *Trans. Ill. Acad. Sci.*, vol. 12, pl. 139-143. Hill's Oak, Jack Oak. (Fig. 7). Distributed over the southern half of Wisconsin. Northward extensions, according to Cheney are "confined almost exclusively to the Jack Pine tracts where the plant is a shrub or

[4] Trelease, l. c., differentiates several forms of *Q. ellipsoidalis* Hill, of which the following are based on the fruit: f. *incurva*, f. *intermedia*, f. *depressa*, f. *coronata*. Specimens representing all of these have been collected in Wisconsin. Miss Ruth Marshall has collected f. *heterophylla*, characterized by deeply dissected foliage, in Sauk County, Wisconsin, 1916.

small tree rarely reaching thirty feet in height." In his notes, Cheney calls this tree *Q. coccinea* Muench. I have examined his notes carefully and there is no doubt in my mind that he described what is now known as *Q. ellipsoidalis* Hill. The scarlet oak, *Q. coccinea* Muench, is not known to occur in Wisconsin.

Q. VELUTINA Lam. Black Oak, Quercitron. (Fig. 5, small dots). Confined to the southern half of the state. It grows on dry uplands in company with red oak, bur oak, white oak, and hickory.

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. XIV.
HYPERICACEAE

WILLARD T. MCLAUGHLIN

The Hypericaceae or St. John's-wort Family in Wisconsin includes the single genus *Hypericum* with eleven species.

The accompanying maps have been compiled from material in the herbaria of the University of Wisconsin and of the Milwaukee Public Museum. Data regarding distribution of plants outside of Wisconsin have also been taken to a limited extent from local floras of recent date.

While most of the species here considered are readily identifiable by use of the manuals several species are quite difficult of interpretation. It is, therefore, with the idea of facilitating recognition and of supplementing the manuals that the following key is included.

a. Styles 5; pods 5 celled. *b*

b. Leaves ovate-oblong, narrowed toward tip, secondary veins conspicuous; mature pod 2 cm. or over in length; large herb .... *H. Ascyron*

b. Leaves linear or oblanceolate, secondary veins not conspicuous; pods less than 1.5 cm. in length; shrubby .... *H. Kalmianum*

a. Styles 3; pods 3- or occasionally 4-celled. *c*

c. Petals yellow, marked with black dots or lines. *d*

d. Profusely branched from base upward; main stem leaves mostly over 2.5 cm. long; pods over .5 cm. in length; petals with black dots on margin only .... *H. perforatum*

d. Branching only above; main stem leaves under 2.5 cm. long; pods under .5 cm. in length; petals and sepals marked with black dots and lines .... *H. punctatum*

c. Petals yellow or pink, not marked with black dots or lines. *e*

e. Leaves broadly ovate, mostly exceeding 1 cm. in width, secondary veins pinnate, conspicuously recurving; pod 2½ to 3 times length of sepals; flowers pink or greenish-purple....... .... *H. virginicum*

e. Leaves smaller, veins not conspicuously recurving; flowers yellow. *f*

f. Pod ovoid-globose, deep red, about 4 mm. broad; styles usually not separating; leaves elliptical-oblong .... *H. ellipticum*

f. Pods short-ellipsoid or somewhat conical, 3.5 mm. broad or less; styles distinct. *g* *g.* Pods acute, much exceeding sepals, about 1 mm. broad; stem fastigiately branched; leaves minute, scale-like .... *H. gentianoides*

g. Pods broader; stem not fastigiately branched; leaves larger. *h*

h. Pods short-ellipsoid, rounded at tip; cymes somewhat leafy-bracted; leaves oblong, ovate-oblong, or elliptic. *i*

i. All the bracts foliaceous and broad........... *H. boreale*

i. Ultimate bracts subulate or setaceous........ *H. mutilum*

h. Pods conic-ellipsoid or slender-conical; cymes naked except for subulate or setaceous bracts; leaves lanceolate to linear-oblanceolate. *j*

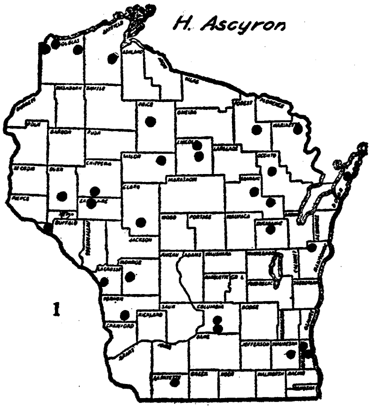
j. Leaves linear to linear-oblanceolate, rounded at tip, narrowed to base, 1- to 3-nerved; cyme lax, usually somewhat unequal; stem slender .... *H. canadense*

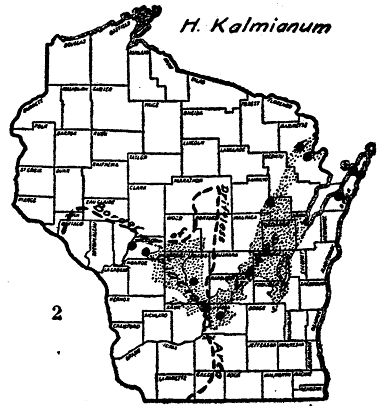
j. Leaves usually lanceolate, 3- to 7-nerved, occasionally in poorly developed plants oblanceolate and blunt; cymes compact due to shortening of uppermost internodes, tending to become flat-topped .... *H. majus*

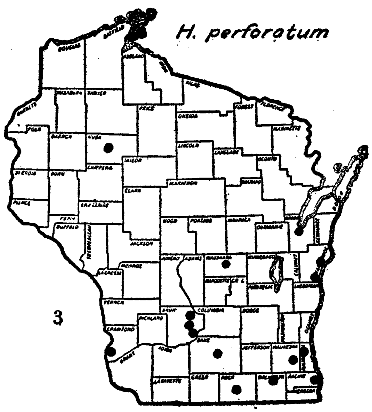
H. ASCYRON L. Great St. John's-wort. (Fig. 1). Of general distribution in low, moist ground.

H. KALMIANUM L. Kalm's St. John's wort. (Figs. 2 and 11). Rocky or stony soil. Represented in Wisconsin by four collections from The Driftless Area, one from Kilbourn, and in the northeastern part of the state from Shawano, Marinette, and Door counties. Outside of Wisconsin the distribution of this species appears to be limited to the shores of the Great Lakes or to localities that were covered by the glacial Great Lakes at the time of the recession of the Wisconsin ice sheet (Fig. 11). In Gray's Manual (seventh edition) the range of this species is given as extending eastward to Pontiac Co., Quebec. No collections from east of Niagara Falls are present in the herbaria of the University of Wisconsin, of the Milwaukee Public Museum, nor, as Dr. I. M. Johnston informs me, in the Gray Herbarium. If, however, this station is assumed to be on the Ottawa River, the occurrence of *H. Kalmianum* there seems explicable on the basis of the suggestion of F. B. Taylor[1] that the Ottawa valley may have afforded an outlet by which the waters of the Great Lakes drained eastward during the late phase of the Lake Algonquin stage. Again, a collection from Sylvania, Lucas Co., Ohio, *L. R. Wilson*, no. 1503, is from the area occupied by Lake Maumee, an extension of Lake Erie at the time of the ice recession. Dr. Johnston lists (in litt.) in

[1] U. S. Geol. Survey Mon. 53: 440. 1915.


H. Ascyron
1


H. Kalmianum
2


H. perforatum
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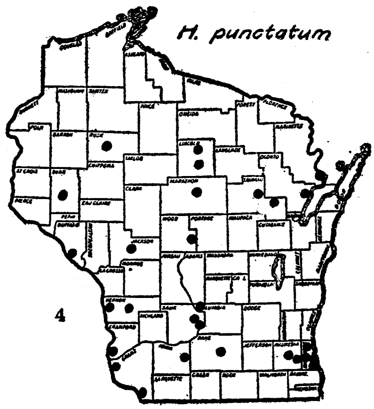
H. punctatum
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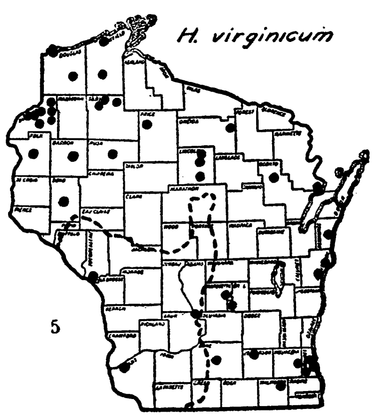
H. virginicum
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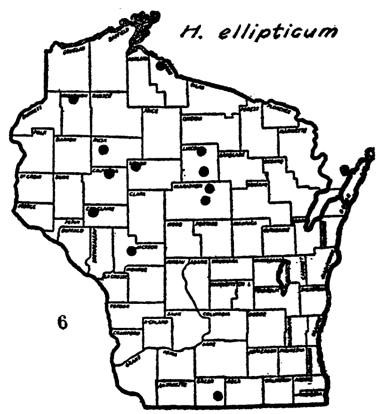
H. ellipticum
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material of the Gray Herbarium a collection from St. Louis, Mo. On the basis of the uniformity of distribution otherwise found this report has been left open to question and is not shown on the map.

Within Wisconsin a similar remarkable correlation between the distribution of this species and the location of the glacial lakes is found. The Green Bay lobe of the ice, at the time of its maximum extension southwestward formed a dam which impounded the waters from the melting ice to form Glacial Lake Wisconsin. This lake, at the time of its maximum elevation covered a considerable territory within The Driftless Area, and, standing at 940 feet above sea level, drained westward to the Black River. In Fig. 2 the approximate extent of glacial lakes Wisconsin and Oshkosh at their maximum is indicated by stippling. The occurrence of *H. Kalmianum* at Black River Falls is thus correlated with this early outlet of Glacial Lake Wisconsin. As the ice front retreated to the northeast a new outlet around the Baraboo Hills was opened. Still later the ice, retreating up the Fox River valley again formed a dam which held in the waters of Glacial Lake Oshkosh. According to Upham[2] the retreat of the Green Bay lobe was somewhat faster than the concurrent recession of the southern part of the Lake Michigan ice lobe which lay upon the area of Glacial Lake Chicago. The two outlets at Portage and Chicago doubtless began to discharge waters of the glacial-dammed lakes on the north and northeast at nearly the same time and each of these lakes (Lake Oshkosh and Lake Chicago) existed independently of each other until the continued recession of the ice lobes permitted the lakes to meet and merge somewhere northeast of Lake Winnebago. The path of the migration of the plant to the south and east was then opened. The stations for *H. Kalmianum* in Shawano and Marinette counties are explained by the migration along the margin of Lake Oshkosh to the present Lake Michigan. We may presume that the plant rapidly established itself, upon the final retreat of the ice, about the shores of the Great Lakes. It is highly specific as to ecological conditions, and so has remained without subsequent extension from the Great Lakes margin. The absence of the plant from New England

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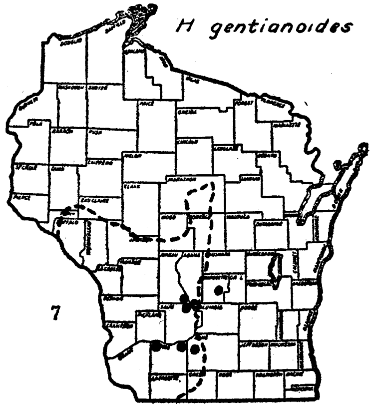
[2] Glacial Lake Jean Nicolet and the portage between the Fox and Wisconsin rivers. American Geologist 31: 105–115. 1903.



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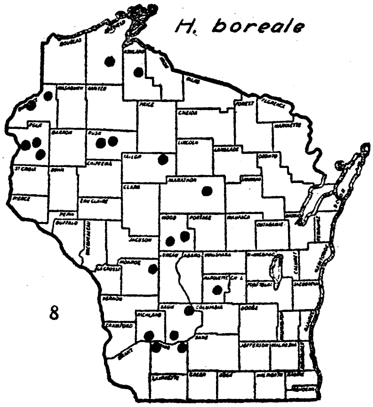

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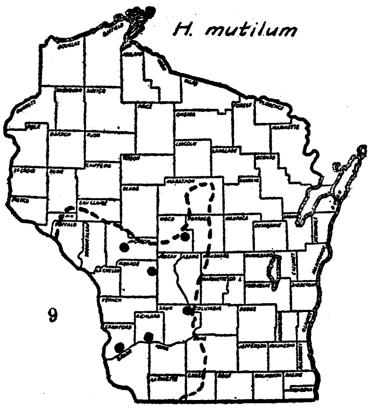

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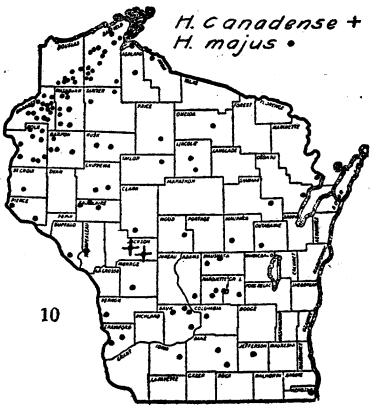

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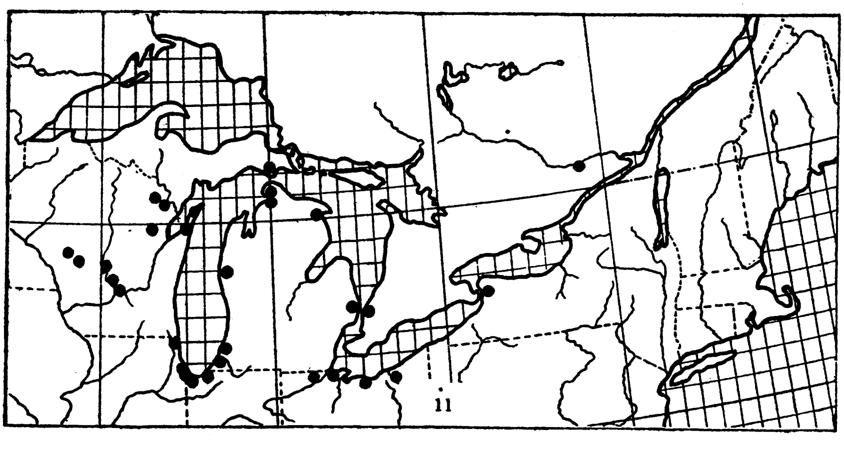
General Distribution of H. Kalmianum



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is notable. Since the present distribution is within the area covered by ice at the time of the last ice advance excepting The Driftless Area of Wisconsin it appears probable that the plant persisted within this unglaciated territory, and, following the glacial lake margins, then migrated eastward. It should be noted that this species is probably closely related to similar shrubby species of *Hypericum* which today have a more southerly range in the United States. Perhaps these southern forms in pre-glacial times, or at least before the last or Wisconsin ice advance were more northern in their range, and upon the advance of the ice migrated to the south leaving *H. Kalmianum* as a relict form within The Driftless Area.

H. PERFORATUM L. Common St. John's-wort. (Fig. 3). A weed in open ground; from Europe. Probably of more general range within the state than the map would indicate.

H. PUNCTATUM Lam. Spotted or Corymbed St. John's-wort. (Fig. 4). Of general distribution in woods or on shaded ground.

H. VIRGINICUM L. Marsh St. John's-wort. (Fig. 5). The occurence of this species both within Wisconsin and in the more general range is limited in a considerable degree to the area covered by ice during the last ice advance. This is due to the preference of the plant for swamps and acid bogs which are found so abundantly within the area of the young drift.

H. ELLIPTICUM Hook. Elliptic-leaved or Pale St. John's-wort. (Fig. 6). Wet ground. Decidedly northern in range.

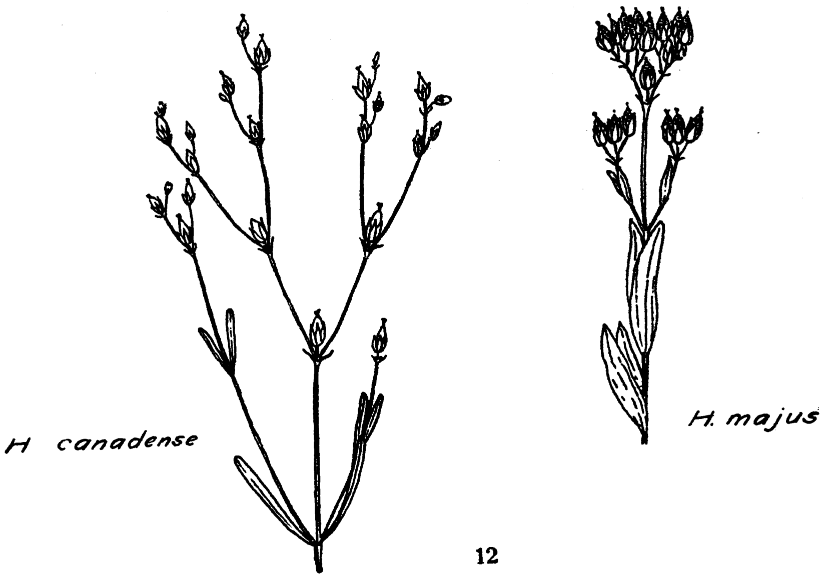
H. GENTIANOIDES (L.) BSP. Orange grass, Pineweed. (Fig. 7). Sandy or rocky ground. In Wisconsin this species seems to be limited to The Driftless Area except for a single collection on a quartzite knob near Montello, Marquette Co. The occurence of this plant on the sand soil of The Driftless Area and on quartzite would indicate a preference for acid soils.

H. BOREALE (Britton) Bicknell. Northern St. John's-wort. (Fig. 8). Bogs and wet sandy or rock shores. As with *H. virginicum* the distribution of this plant is closely linked with that of the bogs and sandy outwash plains resulting from glaciation, and probably indicates a preference for a moist acid substratum.

H. MUTILUM L. Small flowered St. John's-wort. (Fig. 9). Low ground. In general range this species is more southerly than *H. boreale* which it closely resembles except for the setaceous rather than foliaceous bracts. In Wisconsin *H. mutilum* appears to be limited to The Driftless Area. *H. mutilum* var. *minus* has been described from Brazil by R. Keller[3] who states that similar (dwarf) forms are known from North America. Within Wisconsin, dwarf forms have been collected at the Dells of the Wisconsin River and "near Muscoda, Wisconsin, on a rock cliff on the northern side of the river in Richland Co." These collections, as well as the dwarf forms referred to above, are undoubtedly merely shade forms of typical *H. mutilum*. In the cool rocky gorges at The Dells of the Wisconsin River dwarf forms of many different species occur.

H. CANADENSE L. Canadian St. John's-wort. (Figs. 10 and 12). In the herbarium of the University of Wisconsin this species is represented within the state by three collections from Millston and two from Black River Falls in Jackson Co. A single collection from Black River Falls is in the herbarium of the Milwaukee Public Museum, *H. H. Smith*, no. 7000. The meaning of this very limited range for this species within Wisconsin is not yet clear.

H. MAJUS (Gray) Britton. Larger Canadian St. John's-



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[3] Bull. Herb. Boiss. ser. 2, 8 : 184. 1908.

wort. (Fig. 10 and 12). Of general distribution in wet waste lands and on sandy lake shores. In the past much confusion regarding the identity of *H. canadense* and of *H. majus* has existed. Linnaeus (Species Plantarum, 1753) described *H. canadense* as having linear-lanceolate leaves and conical red capsules twice the length of the sepals. In the fifth edition of Gray's Manual *H. canadense* var. *majus* was described as a large form, one to two feet high, with lanceolate leaves 1½ inches long and ¼ inch wide. Britton[4] raised the variety to specific rank. The report of Keller[5] of the occurrence of *H. canadense* var. *minimum*, a small, few-flowered form with oblong, obtuse leaves, from Wisconsin, is doubtless based on material of *H. majus* such as is common on the sandy shores of the northern lakes. Here the plants, growing under adverse conditions, are frequently no more than a few cm. high, but all variations from these dwarf forms to the coarser typical *H. majus* as originally described by Gray may be found. These dwarf forms, moreover, although at times bearing but four or five capsules, nevertheless evince a tendency to form a compact, flat-topped cyme by the shortening of the uppermost internodes, such as is characteristic of *H. majus* generally (Fig. 12). In *H. canadense*, on the other hand, the cyme is much more lax. The capsules in these small specimens are also broader at the base and more obtuse than is typical generally of the slender-conical capsule of *H. canadense*.

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[4] Mem. Torr. Club 5: 225. 1894.
[5] Bull. Herb. Boiss. ser. 2, 8: 188. 1908.

NOTES ON CERTAIN SYRPHUS FLIES RELATED TO XANTHOGRAMMA *(DIPTERA SYRPHIDAE)* WITH DESCRIPTIONS OF TWO NEW SPECIES

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University of Wisconsin

The genus Xanthogramma has never been thoroughly characterized and as a result several species have been described as belonging to it when they should be treated as true *Syrphus* forms. Verrall's characterization of the genus is the most complete but he does not mention the black-based scutellum, although he does remark on the shortness of the antennae.

The genus Xanthogramma Schiner may be characterised as follows:

XANTHOGRAMMA *Schiner*

Syrphus-like flies with strong contrasting black and yellow markings, particularly on the sides of the thorax; face yellow, receding below; front as long as the face; scutellum distinctly black at the base, margined with yellow; *antennae short, the third joint with little more and usually less surface area than the first two segments combined* (Plate V, figure 1); abdomen broadly ovate, the sides emarginate; otherwise very much like *Syrphus*.

This characterization limits the genus to one known species in North America, *X. flavipes* Lw.

The American forms which were originally described as Xanthogramma are *felix* O. S., *divisa* Will., *aenea* Jones, *tenuis* Osb., *fragila* Fl. and *habilis* Sn. *Syrphus infuscatus* and *weborgi* new species belong to this group. *X. flavipes* Lw. was originally described as a *Doros.*, and *S. emarginatus* was first placed in the genus *Scaeva* by Say, transferred to *Syrphus* by Wiedemann and to *Xanthogramma* by Williston.

The species *emarginatus* Say, *felix* O. S., *divisa* Will., *aenea* Jones, *fragila* Fl., *infuscatus* n. sp. and *weborgi* n. sp. constitute a rather distinctive group belonging to the genus *Syrphus*.

They all have yellowish thoracic side stripes but the third joint of the antennae is larger than the other two combined. The larval forms of those that are known indicate a very close relationship and it would probably be desirable to erect a sub-genus for the group. They should not be confused with the species which have whitish or slightly yellowish thoracic side margins and narrow non-emarginate abdomens, such as *Syrphus guttatus* Fall. *(habilis* Sn.) *S. tenuis* Osb., and *S. cinctellus* Zett., which are now regarded as true representatives of *Epistrophe.*

The purpose of this paper is to show the relationships of the *emarginatus* group. The following key will separate the forms known from North America. With the descriptions of the species a few biological notes are given.

1. Yellow crossband on second abdominal segment entire although frequently greatly emarginate and sometimes narrowly separated 2
   All the bands distinctly separated into spots which also do not reach the side margins 5
2. Yellow markings on the second abdominal segment do not reach the side margins ..... *felix* O. S.
   Yellow markings on the second segment extend over the side margins 3
3. Antennae blackish, wings slightly smoky, front of female with black shining stripe, frontal triangle of male with large black spot ..... *infuscatus* n. sp.
   Antennae reddish, wings hyaline, the black stripe on the front of the female tapers to a point before reaching the antennae, frontal triangle of male mostly yellowish 4
4. Anterior corners of the second and third abdominal segments yellow ..... *emarginatus* Say
   Anterior corners of the abdominal segments black ..... *aenea* Jones
5. Bases of front femora black, sides of oral opening dark 6
   Front legs entirely yellow, anterior corners of third abdominal segment yellow, face entirely yellow ..... *weborgi* n. sp.
6. Abdomen oval, larger species ..... *divisa* Will.
   Abdomen with nearly parallel sides, smaller species ..... *fragila* Fl.

Syrphus emarginatus (Say)

Plate V, Figures 2, 3, 4, 5.

Scaeva emarginata Say, 1823, Jour. Acad. Nat. Sci. Phil. 3 : 91; 1859, complete works 2 : 79. Fla.

Syrphus emarginatus Wiedemann 1830, Auss. Sw. Ins. 2 : 119. Fla.

Xanthogramma emarginata Williston, 1886, Synopsis, 93. Fla., Pa., N. H.; Aldrich 1905, Cat. 369; Graenicher 1910, Bul. Wis. Nat. Hist. Soc. 8 : 38. Wis.; Fluke, 1922, Trans. Wis. Acad. Sci. Arts and Let. 20 : 236. Wis.

Syrphus emarginatus Curran 1924, Kans. Univ. Sci. Bul. 15 : 164. Also recorded from New Eng., N. Y., Ohio, S. Car.

A variable species, middle crossband always entire, first and third bands usually divided but often entire or nearly so; if entire greatly emarginate. First band reaches the side margins, second and third usually but they may sometimes be separate. Front and frontal triangle largely yellow. Length 9 to 11 mm., a few specimens are as short as 7 mm.

MALE – Face, cheeks, and oral margin yellow; frontal triangle mostly yellow with two small black spots just above the antennae, vertex black. Facial tubercle large and well rounded, shining, devoid of pollen and pile. Pile of face yellow, becoming black above on the sides, black on the frontal triangle and vertex. An area above the antennae shining and devoid of pile or pollen. Antennae of medium size, first two segments mostly yellowish orange, third yellowish below, arista black.

Thorax shining metallic bluish green, the sides with yellow margins, pile yellow to light brown, heavier and darker on the sides. Pleura with very indistinct yellow areas, the pile brownish. Scutellum opalescent, darker on the corners, the pile rather long and mostly black.

Abdomen opaque black, semi-shining at the apical margins of the segments, with three principal cross bands. First segment with the sides yellow, the color being continued on the anterior angles of the second segment. Spots on the second segment well separated but always reach the side margins with only a little attenuation. Band on third segment is broad, occupying at least half the width of the segment, placed a little to the base of the segment, deeply emarginate in the middle behind. Usually this band reaches the side margins but is nearly always greatly attenuated and the yellow connects with the yellow anterior corners. Third band similar but nearly always interrupted and is more often separated from the side margins. The fifth segment yellow with a narrow elongated black triangle in the middle. Posterior margin of segment three narrowly yellow, black on the sides; segment four more broadly yellow with usually an anterior projection forward in the middle. The anterior margin of segment four is also narrowly yellow. Venter yellow with yellow pile to the middle of segment three, black beyond.

Legs yellow; posterior pair of legs with dark rings on the femora and tibiae, the tarsi reddish to brownish. Sometimes the coxae are darkened. Wings hyaline, stigma yellowish.

FEMALE – quite similar, abdominal bands are narrower and the yellow spots of the second segment frequently united, also extend forward on the sides to connect with the yellow anterior corners. Fifth segment darker. The front is yellow with a pointed black area reaching from the ocelli to half way to the antennae, sometimes reaching or almost reaching the two spots just above the antennae. Antennae larger, legs paler.

Described from nearly fifty specimens, from New Jersey, New York, Tennessee, and Wisconsin.

IMMATURE STAGES (Plate VI, Figures 24, 25, 26, 27.) The larvae of this species have been taken at numerous times on goldenrod, feeding upon *Macrosiphum rudbeckiae* Fitch; and particularly on wild raspberry, feeding upon *Amphoraphora rubicola* (Oest.). They are easily reared in almost any kind of cage but need special treatment as soon as they are full grown. Within a few days after they refuse any more food they should be placed in a flower pot containing growing grass, dead leaves, and like material, and placed out of doors so that they get the rain and some sunshine. The pot should be caged over so that the larvae cannot escape. They will then readily pupate and emerge.

EGG: The egg is very similar to that of *S. divisa* Will. No character has been found to separate them except perhaps the size, as the eggs of *emarginatus* are usually a trifle smaller.

Curran[1] states that the eggs are invariably deposited upon the petiole of the leaves.

LARVA: Very similar to the description and pictures by Metcalf[2] of his *X. divisa* (=*S. weborgi* n. sp., not the *S. divisa* of Will.) The full grown larva is oval in shape and very flat. It measures 10.5 mm. in length and 4.95 mm. in greatest width. The hibernating larvae are ashy grey in color but vary from a light pinkish to a tan or brownish color. It is not to be confused with the beautiful reddish tan of *S. divisa.* The lateral margins

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[1] Kans. Univ. Sci. Bul. *15* : 164, *1924*.
[2] Maine Ag. Expt. Sta. Bul. *263* : 154, 1917.

have the characteristic serrations in groups of three with a much smaller serration between the groups. These larger serrations each bear at their tips a short pale spine, the smaller ones devoid of spines. The entire body surface is finely papillose, the papillae occurring also on the serrations and on most of the posterior respiratory appendage.

Measurements of the posterior respiratory appendage are given in the accompanying table (Table I). As a basis of comparison the measurements of the three species, whose life histories are known, are given also. The measurements of *S. weborgi* are as reported by Metcalf. The figures for *S. emarginatus* and *S. divisa* are from observations made by the author.

In Table II measurements of the spiracular angles of *S. emarginatus, S. divisa* and *S. weborgi* are given. The method of taking these angles is explained in Wis.Agr.Expt.Sta.Res.Bul. 93, p.14 (1929).

TABLE I. *Measurements of the posterior respiratory appendage of the larvae of three species of Syrphus. Measurements are in millimeters.*

	S. weborgi	S. emarginatus	S. divisa
Length of post. resp. tube	0.9	0.744	0.896
Width at tip	0.494	0.456	0.387
Height at tip	0.27	0.267	0.193
Diameter of circular plate	0.0712	0.069	0.058
Distance between circular plates	0.085	0.096	0.062
Width of one tube	*0.230	0.221	0.180
Distance between spiracles II and II'	*0.293	0.312	0.240
Av. length of spiracles I & I'		0.072	0.077
Av. length of spiracles II & II'	0.134	0.0865	0.082
Av. length of spiracles III & III'		0.080	0.082
Av. width of spiracles	0.015	0.016	0.014

TABLE II. *Measurements of the spiracular angles of* Syrphus emarinatus, S. divisa, and S. weborgi.

Species	Angles in degrees			
	Incline of A	B	C	Incline of D
Syrphus emarginatus	+53	65	85	—23
Syrphus divisa	+32	74	82	— 8
Syrphus weborgi	+40	71	81	—12

Four parasites of *S. emarginatus* were reared, all belonging to *Homotropus bicapillaris* var. *albopictus* Davis. These were

* Measurements by the author. The remaining measurements of *S. weborgi* were made by Metcalf. All the measurements on *S. emarginatus* and *S. divisa* were made by the author.

determined by R. A. Cushman. Two of the parasites emerged indoors during the winter. The syrphid larvae remained outside until the last of December and were then brought into the greenhouse. The larvae soon pupated, but in less than four weeks produced the parasites. This parasite thus winters over in the host larvae.

Syrphus felix (O.S.)

Plate V, Figures 6, 7.

Xanthogramma felix Osten Sacken 1875, Bull. Buff. Soc. Nat. Sci. 3 : 67; 1878, Cat. Dipt. 126, 247, and 215., N. Y., Pa., Ill.; Williston 1882, Proc. Phil. Soc. 20 : 311; 1886, Synopsis, 91. Conn.; Aldrich 1905, Cat. 369. Recorded also from N. Y., N. Eng., Ohio, N. Jer., and Wis.

Abdomen with three distinct crossbands, all well separated from the lateral margins; the first and third usually interrupted, the middle one always continuous although often deeply emarginate. Front and frontal triangle mostly black.

MALE: Length 10 to 11 mm. Face yellow and only subshining, tubercle prominent; cheeks also yellow but there is a slight darkening about the jaws; pile of cheeks and face light in color, becoming dark along the eyes just below the antennae. Frontal triangle almost entirely yellow with two small black dots just above the bases of the antennae, pile black; the shiny area above the antennae devoid of pile or pollen. Vertical triangle black with black pile. Antennae mostly reddish on the first two segments, darker on the upper two thirds of the third segment.

Thorax bright shining greenish to bluish, side stripes pale, pile pale; scutellum mostly yellow or opalescent, darker at the basal corners, the pile yellow and black mixed, mostly black on the edges. Pleura with indistinct side spots of yellow.

Abdomen elongated more than related species, with three principal yellow crossbands, the first (on second segment) separated into two large spots which are well separated from the lateral margins. First segment yellow on the side corners, which is also found slightly on the anterior corners of segment two. Third segment with a broad, deeply emarginate posteriorly, band which is well separated from the lateral margins; anterior corners and a very narrow median band at the apex, not reaching the sides, yellow. Fourth segment with two large yellow spots which are separate from the side margins but which attenuate and connect with the anterior yellow corners; a very narrow basal line and broader apical margin yellow. Fifth segment mostly yellow with a broad black band on the disc. Venter indeterminately dark, pile of first, second and third sternites long, pale and kinky.

Legs mostly pale, hind legs infuscated with brown but pale at the bases and tips of the femora, bases and tips of the tibiae, and the metatarsus. Wings hyaline, stigma yellowish.

FEMALE similar, except the abdominal bands are narrower, the side stripes brighter and the front black to the base of the antennae, with sides yellow, a distinct yellow broad Y-marking just above the antennae. Abdomen usually shows the characteristic greatest width at the tip of the second segment, although this is not always reliable.

Described from three males, one caught at Madison Sept. 11, 1920, one at Columbus, Wis. June 15, 1924 (Fluke); and the third reared which emerged indoors February 1930; and twelve females with the following data: three from Ames, Ia., July 7, 1923; one from Tenderfoot Lake, Vilas Co., Wis., 1913, (W. S. Marshall); one from Door Co., Aug. 25, 1927; four from Madison, Wis., 1929, May 28, July 15, July 27 and Sept. 31; two from Tuxedo, N. Y., July 11 and 16, 1929 (Curran).

I have one male reared adult which comes within the limits of my understanding of this species. A careful study of the larva, pupa, and posterior respiratory appendage shows very little, if any, difference between *felix* and *emarginatus*.

The measurements in millimeters of the posterior respiratory appendage of *S. felix* are: width at tip 0.466; height 0.278; width of one plate 0.230; total length dorsal view 0.720, side 0.624, and ventral 0.576; width at base dorsal view 0.624, side 0.432; distance between circular plates 0.096; diameter of circular plates 0.58; distance between the mesal margins of spiracles II and II' 0.336.

Syrphus aenea (Jones)

Xanthogramma aenea Jones 1907, Jour. N. Y. Ent. Soc. 15 : 93, Nebr.

The description given below is of a male from Omaha, Nebraska collected by L. T. Williams August 26, 1913, and determined by Wehr as *aenea*. I do not believe this is the male of *aenea* – and it seems possible that *aenea* as described by Jones is a synonym of *emarginatus*. The type specimen is a female, which is apparently lost.

MALE – Length 12 mm. Face, oral margin and cheeks entirely pale yellow, very lightly brownish on the upper mouth edge and lower part of tubercle, with light colored pile; in profile the face has a rather prominent well rounded tubercle which is broadly shining, devoid of pollen and pile. This stripe reaches base of antennae. Front is mostly yellowish to light brownish with two prominent black spots just above the antennae. Pile on front and sides of antennae black. Antennae, first two segments yellow, 3rd missing. Vertex black with black pile.

Thorax shining dark greenish to black with prominent broad yellow side margins, pile tawny. Scutellum almost all yellow with yellow and black pile — mostly black. Pleura yellow and black with indistinct separations.

Abdomen with three broad yellow bands. First segment, black with anterior corners yellow. Second segment, with a broad band which is narrowly interrupted in the middle but goes over the side-margins in nearly full width. On the sides the band spreads forward so that it appears attenuated posteriorly, but the anterior corners reach forward so that by looking from below the yellow reaches to the edge of the preceding segment. This is also true of the other bands. The widest part of this band is greater than one-half the width of the segment. Third segment, band broader and greatly emarginated behind, posterior margin of segment yellow. Fifth segment, band even broader but also more emarginate behind, so that band is nearly interrupted. Anterior margin narrowly and posterior margin broadly yellow. Fifth segment, almost entirely yellow — with only a narrow star-like triangular black spot. Venter yellow with indistinct light brownish areas on sternites 3 and 4. Pile on 1st and 2nd sternites long yellow; on third yellow anteriorly, shorter and black posteriorly; on 4th and remaining sternites appressed and black. Genitalia yellowish — mostly black pile.

Front two pair of legs yellow with yellow pile. Hind legs mostly brown with the coxae, trochanters, bases of femora and knees light brown or yellow. Middle coxae slightly brownish.

Wings hyaline — stigma light brownish.

Similar to *infuscatus* but lacks infuscation of wings, antennae lighter, bands broader and reach side margins more.

Prof. M. F. Swenk kindly loaned this specimen for study.

Syrphus infuscatus n. sp.

Plate V, Figures 8, 9, 10

Xanthogramma aenea Fluke (not Jones). Trans. Wis. Acad. Sci. Arts & Let. 20 : 236, 1922.

Wings tinged with brown, side stripes of the thorax conspicuous, abdomen with three yellow cross bands which are separated into spots in some specimens. Antennae large and almost completely black. Length 11 to 13 mm. Eyes bare.

MALE: Face entirely yellow with a slight indication of opalescence next to the eyes nearest the oral opening, face is widest about half way between antennae and the mouth, tubercle large and shining; pile light except along the sides and a little below the antennae, where it is black. Frontal triangle black and shining, yellow on the sides, but the black area extends back to a point where it reaches the juncture of the eyes. No pile just above the antennae on the shiny parts, other areas with black pile. Cheeks pure yellow with sparse pale pile. Vertical triangle black with black pile, tawny behind, becoming lighter on the lower occiput. Antennae nearly all black, with a very little red at the base of the third segment in some specimens, arista black.

Thorax shining brassy colored with rather bright yellow side margins which are somewhat opalescent in some specimens, pile light yellow to brownish, longer and thicker on the sides. The pleural spots are not so bright, being of a more opalescent color. Scutellum yellow with the base narrowly black, pile rather long and nearly all black, only a few yellow hairs in front on some specimens.

Abdomen black with three pairs of prominent yellow crossbands, the middle one of which is usually entire but sometimes interrupted; of sixty-one male specimens fifty-four have this band entire, although sometimes deeply emarginate behind, and the other seven entirely separated.

First segment is shining and broadly yellow on the sides.

Second segment sub-opaque black; the yellow band broadly interrupted and reaching the side margins by almost its entire width, slightly attenuated on the rear margin; the inner ends rounded; the band occupies about one half the width of the segment and is situated mid-way in the segment. Band on the third segment variable, sometimes interrupted, other times entire or sub-interrupted, on most of the specimens it is separated from the side margins, on a few touching the sides by the anterior corners, and on a few rather broadly reaching the sides; usually slightly oblique as is characteristic of this group of flies, the fore margin of the band nearer the 2nd segment than the rear margin to the 3rd segment. Third band similar but nearly always interrupted and more oblique, the inner ends nearly touching the rear margin of segment three; scarcely reaching the side margins. Fifth segment nearly entirely yellow, with only an indistinct triangular black area in the middle. Posterior margin of segment three narrowly yellow, of segment four more broadly yellow. The black of the posterior segments more shining than segment two. Venter is colorless but the spots of the tergum show through.

Front and middle legs yellow with the coxae and indistinct basal areas of the trochanters black. Hind legs mostly black, with the trochanters, narrow base and tip of the femora and tibiae reddish.

Wings infuscated along the costal margin, very dilutely infuscated over the rest of the wings.

FEMALE – Larger, nearly 12 to 13 mm. long, abdomen more broadly oval. Antennae larger and blacker. Front long black shining, with yellow on the sides, constricting the black stripe at the depression of the front. Side stripes of the thorax bright yellow, pleural spots also brighter. Legs lighter, front coxae yellow. Wings darker, especially on the costal margin.

Abdominal bands similar to the male with the usual variations, the bands however are narrower and reach the side margins more broadly, black more shining.

A very beautiful species which should be easily recognized by the smoky wings. Its nearest relative appears to be *S. emarginatus* Say but may be told from this species by the darker wings, larger size, blacker antennae, darker front and frontal triangle, etc. In teneral specimens of *infuscatus* the wings are often more hyaline and may be confused with *emarginatus.* The black frontal triangle of the male and the black front of the female along with the larger and blacker antennae should determine this species even though the wings may be quite hyaline.

Holotype male collected by the author Sept. 13, 1929 at Madison, Wis. Allotype female collected by J. H. Lilly Aug. 26, 1929, at Madison, Wis.

Paratypes, 24 specimens collected by the author at Madison on the following dates: Aug. 1, 1917 (H. K. Harley) 1 female; Aug. 31, 1917, 4 males; Sept. 6, 1917, 1 male; Aug. 17, 1918, 1 male; Aug. 26, 1929, 1 male; Aug. 27, 1929, 2 males and 3 females; Aug. 30, 1929, 3 males and 3 females; Sept. 7, 1929, 2 males and 1 female; Sept. 13, 1929, 2 males; and Aug. 26, 1930, 2 females and 1 male; in the author's collection. 50 specimens collected by C. H. Curran at Tuxedo, New York, 4 females Aug. 28, 1928; and 46 males, three August 20th, twenty-eight August 24th, one August 26, thirteen August 28, and one with no date; in the American Museum of Natural History. One male (J. H. Lilly), one female (T. C. Allen) Gays Mills, Wis. Aug. 28, 1930.

I do not believe this species can be either *felix* O. S. or *aenea* Jones. The original type of *aenea* is lost and the male in the Nebraska collection is too imperfect to permit either positive identification or a description as new. Numerous rearings of *emarginatus* have always yielded typical specimens except two which might come within the limits of *felix.* The question will be settled more satisfactorily when the immature stages of *infuscatus* are described.

Syrphus weborgi n. sp.

Plate V, Figures 11, 12, 13, 14 and Plate VI, Figure 15

Xanthogramma divisa Metc. (not Will.) Me. Agr. Exp. Sta. Bul. 263 : 154, 1917.

The three principal bands of the abdomen distinctly interrupted and well separated from the lateral margins. Front of female and frontal triangle of male largely black. Wings hyaline, stigma brownish. Side stripes of the thorax distinct in the female, less so in the male.

MALE: Length (three specimens) 10.5 mm. Face yellow with a broad shining stripe, tubercle prominent, cheeks and lower mouth edge entirely yellow; there is a very small indefinite dark area next to the eyes midway between the face and the cheeks, which shows a close relationship with *S. divisa.* Frontal triangle with a large black shining area which is dusted with pollen toward the vertex, sides yellow. Just above the antennae and midway between them is a characteristic yellow marking, wider and more conspicuous than that found on *S. infuscatus* or *S. divisa.* Pile of frontal triangle black, extending down the side a short distance below the antennae, rest of pile of face and cheeks pale, inconspicuous. Vertical triangle black with black pile. Antennae dark, reddish at the bases of the first two segments and broadly reddish on the under-side of the third; arista dark, pale at the extreme base.

Thorax dark metallic bluish green, side stripes inconspicuous, pile brownish, heavier on the sides. Pleura with inconspicuous yellowish markings. Scutellum dark from above, yellow when viewed from the side, pile pale in front, longer and black posteriorly.

Abdomen black, semi-shining, with three pairs of prominent spots, which are well separated from the side margins. First segment with the sides yellow; this is continued on to the next segment, making the anterior corners yellow. Spots on the second segment situated about mid-way between the fore and apical margins and occupying a little less than half the area; inner ends rounded, the very narrow apical margin yellow. Second pair of spots similar except they are larger and are nearer the preceding segment, inner ends not so pointed; extreme base and apical margins yellow. Third pair of spots nearly like the second, but almost touch the basal margin of the segment; basal margin thinly yellow, a little broader on the sides, apical margin more broadly yellow but black near the side margins. Fifth segment with an arcuated band of black which leaves the tip and sides of the segment yellow. Venter transparent.

Legs yellow, all the coxae, trochanters, hind tarsi, indefinite mid band on the hind femora, and a broader band on the hind tibiae dark brown to black. Wings very faintly tinged with yellow, stigma brownish.

FEMALE: Similar but with the following differences: front black and extending to the base of the antennae, expanding below, with a quadrate yellow spot just above the antennae and midway between them; antennae larger, side stripes of the thorax distinct; abdominal spots narrower and closer together; there are only small yellow spots on the anterior corners of segment three and the apical margin of this segment is yellow only in the middle, the fourth segment quite similar; legs more yellow, the fore and middle coxae and trochanters almost entirely yellow. In a few specimens the middle pair of spots are sub-united.

Holotype female Aug. 25, 1927, taken near Fish Creek in Door County, Wis. by the author; allotype male, same locality, August 10, 1929.

Paratypes 36 females, same locality, Aug. 24, 1927, three specimens; Aug. 25, 1927, eleven specimens; Aug. 26, one specimen; Aug. 28, 1927, two specimens; Aug. 31, 1927, one specimen; Sept. 1, 1927, seventeen specimens; Madison, Wis. July 30, 1929, one specimen; one male Tuxedo, N. Y. Aug. 2, 1928, collected by C. H. Curran, and one male Niles, Mich. July 6, 1928 taken by L. G. Gentner.

Types in the author's collection.

A very distinctive and uniform species which should be readily recognized. It might be confused with *S. divisa,* to which it is evidently closely related, but that species is much darker; legs, abdomen, face, etc. The entirely interrupted bands distinguished it from *S. felix.* Its abdomen is also more oval than *felix.*

When the specimens were taken in Door County in 1927, they were thought to be representatives of *divisa* Will. until Curran pointed out that *disjectus* Will. is a synonym of *divisa.* Metcalf also considered his Maine specimens *divisa* but they are conspecific with *weborgi* n. sp. This determination is made possible by the kind loan of the specimens reared by Dr. Metcalf. A complete description of all stages is made by Metcalf in Maine Agr. Expt. Sta. Bul. 263, 1917.

Syrphus divisa Will.

Plate VI, Figures 16, 17.

Xanthogramma divisa Williston 1882, Proc. Amer. Phil. Soc. 20 : 311; 1886, Synopsis 92, Wash., N. H.; Aldrich 1905, Cat. 369.

Syrphus disjunctus Williston (Not Macq.) 1882, Proc. Amer. Phil. Soc. 20 : 314.

Syrphus disjectus Williston 1886, Synopsis, 72.–Wash.; Snow 1892, Kans. Univ. Quart. 1 : 36, – Colo.; Aldrich 1905, Cat. 365; Osburn 1908, Can. Ent. 40 : 5. – Br. Col. Synonomy by Curran.

Syrphus divisa Curran Bulletin American Museum of Natural History 61 : (Art. 2) 51. 1930.

A rather common fly in Wisconsin caught mostly during the late summer. It is characterized by having three pairs of yellow spots on the abdomen, otherwise quite dark.

MALE: Length 7 to 10 mm. Eyes bare. Face and cheeks yellow with a dark shining area between the eyes and the oral opening. The face has a broad shining stripe with a rather prominent tubercle, pile and pollen light except on the sides above. Frontal triangle black with black pile; the black area narrowed above, broadened toward the antennae with a very small yellow emargination mid-way between the antennae and just above them. Pile of cheeks pale becoming yellow above on the occiput, black on the black vertical triangle. Antennae small, dark with reddish below on the third segment; the first two segments mostly reddish.

Thorax dark blue, shining, with very indistinct pale side margins, most of this paleness may be due to light colored pollen. The pleura almost entirely dark with yellowish pile. Pile of the dorsum of the thorax brownish. Scutellum almost dark, but appears dark yellow when viewed from the sides, except the black basal area; pile mostly black, longer on the edges of the scutellum.

Abdomen opaque black, shining a little on the fore and apical margins of the segments; with three pairs of prominent yellow spots, all well separated and not reaching the side margins, somewhat quadrate in outline. First segment shining, faintly yellow on the sides but does not encroach on the second segment (in *weborgi* there is nearly always a small amount of yellow on the fore corners of the second segment); spots on the second segment oval and well separated, they almost reach the side margins but in all examples which I have examined they are never touching; spots on the 3rd and 4th segments near the bases of the segments, nearly quadrate but the inner sides less than the outer margins; fourth segment with a narnow, yellow apical margin in the middle; fifth segment with the anterior corners broadly, and the apical margin narrowly, yellow.

Legs mostly dark, the first pair yellow from the basal third out, second pair similar but there is a smudge on the apical part of the tibia and the tarsi are light brownish; on the third pair the trochanters, extreme bases of the femora, and knees are yellow. Wings slightly smoky, stigma yellowish. Halteres yellow, their stalks brown.

FEMALE similar. The front mostly black, yellow only below on the sides, with that peculiarly shaped yellow spot in the black area just above the antennae; antennae darker, almost all black; thorax stripes more distinct, pile of pleura white; abdominal spots longer but narrower, yellow of the legs more pronounced.

A very uniform species which closely resembles *S. weborgi. S. divisa,* however, is easily separated because of its dark form; it is also smaller. The larvae of this species feed upon *Chaitophorus populicola* Thom. on *Populus spp.* Described from 39 specimens. Also recorded from British Columbia, New York and New Hampshire.

IMMATURE STAGES (Plate VI, Figures 18, 19, 20, 21, 22, 23). The larvae of *S. divisa* were first observed in July, 1924, near Columbus, Wis. Their unusually flat appearance and striking color immediately attracted attention although they looked somewhat like a dead area or scale of the leaf. They were resting on the top of the broad leaves of young vigorous shoots of balm of Gilead. The growing tips of these shoots were infested with an aphid which was later determined as *Chaitophorus populicola* Thom. The larvae were well scattered, never more than two were found on each twig. After a close diligent search about a dozen specimens were gathered, placed in pill boxes with some of the aphids from the tips of the twig.

All of the larvae, which were of various sizes grew rapidly, feeding on the aphids given them. They would then seek any depression in the pill boxes, become senescent, finally withering and dying. No clue to the identity of the species was secured that year or the next, although quite a few of the larvae were collected.

During the season of 1929 they were again noticed feeding upon the same aphid which was very plentiful on quaking aspen in the vicinity of Madison. In the meantime, one warm day the last of July while collecting in a woods near Madison with my young son, we came across a few small aspen trees infested with aphids, among the branches of which we observed with difficulty the adults of *S. divisa.*

Numerous specimens were caught and after some time of watching one female was observed apparently laying eggs among the colonies of plant lice. The fly was so alert that it was some minutes before she was observed to deposit an egg. This was found in a crotch formed by a small twig and a leaf petiole. As soon as the egg was laid the fly was captured, and proved to be *S. divisa.*

The single egg was oviposited July 30, 1929, and hatched four days later. The young larva exhibited the characteristic shape and color of *S. emarginatus* larvae although it was a trifle pinkish. After two days an extended trip out of town was necessary and with the anxious idea to rear the species the specimen was taken along with the anticipation of finding enroute plenty of food for it. None of the same aphids were found and although offered other species the syrphid larva died.

About this same time eight of the full grown tan colored larvae were placed in a flower pot containing a little grass, dead leaves, and sticks. This was covered over with cheese cloth and placed out of doors under a tree.

An examination on Aug. 15, disclosed one pupa skin and a syrphid fly nearly dead within an inch of the pupa case. This fly, while not entire normally colored, was easily identified as a male *S. divisa.* The pot of larvae was brought into the laboratory about the first of December and Jan. 20, 1930 a female emerged. This settled without any doubt the identity of the species.

There are apparently two generations of this species in Wisconsin, adults appearing in June and again in August, although some are caught at almost any time during the season. They will be taken most commonly where Populus spp. occur.

EGG – Length 0.768 mm., width 0.264 mm. The egg is white and shows no distinct differences from those pictured by Metcalf for *Syrphus weborgi.* The chorion pattern exhibits the characteristic "8-rayed spider webs, or hexagonal wheels". Here also the transverse arms are parallel, rather close together. These patterns can also be described as diamond shaped areas, all contiguous like honey comb, with the four corners consisting of a slightly elevated body; each diamond being crossed transversely by two close parallel arms or lines. These parallel arms appear to be closer together in this species than those pictured by Metcalf for *weborgi.* Considerable irregularity occurs in the shapes of these markings and the transverse parallel arms may run slightly oblique around the egg.

LARVA: Length, contracted, 7 mm., width at widest point about 4 mm.

This larva is readily recognized by its flat appearance (although well fed specimens are somewhat rounded) but particularly by the tan colored band which occupies in general the posterior half of the body. This band is oblique in shape, pointed anteriorly on about the middle segment (6th?). On this segment the tan color occupies only the middle area or disc, the sides are yellow. The following three segments are pink, the last of the three being only irregularly tan on the dorsum. The anterior three (exposed) segments and the posterior two are yellow.

Along the sides the larva has the characteristic papillae in groups of three to each segment; at the end of each papilla is a short stubby, pale spine. Between each two groups of papillae is a small papilla, lacking a spine; but these occur only posteriorly on the last five segment divisions.

Integument is very finely papillose with no vestiture. Segmental spines very short, pale, and almost inconspicuous.

Posterior respiratory appendage. The tip of the tube slants up so that measurements vary in relation to ventral or dorsal aspects, the dorsal being longer. Dorsal length 0.896 mm., ventral length 0.744 mm., width at tip of organ 0.387 mm., width at base 0.504 mm., height 0.193 mm.

The spiracles are straight and vary in apparent length from 0.072 mm. to 0.082 mm. with an average of 0.077 mm. Complete measurements are given in comparison with *S. emarginatus* in Table I. The entire tube is longer and more slender than usual in this group. It is broad at the base and curves evenly and gradually to the middle, the sides are then parallel for a short distance, finally widening at the tip.

This larva is the most beautiful of the Syrphidae I have ever seen, exceeding in its delicate tints other members of this group.

PUPA – Length 5.25 mm., exclusive of the posterior respiratory appendage; width approximately 3 mm. The shape is characteristic of this group, similar to *emarginatus* and *weborgi.* The larval color is absent, having instead a buff or light brown color with irregular black cross bars on 3rd to 6th segments. 8th and 9th segments usually with black dots on the mid-dorsum.

Syrphus fragila (Fluke)

Xanthogramma fragila Fluke, Trans. Wis. Acad. Sci. Arts & Let. 20 : 21, 1922.

Very closely related to *divisa* Will. and may be only a variety but the small size, narrow abdomen, yellow antennae and yellow frontal triangle seem to indicate that it is a distinct species.

EXPLANATION OF PLATES

All drawings were made with the aid of the camera lucida, thus direct comparisons of like objects can be made.

PLATE V

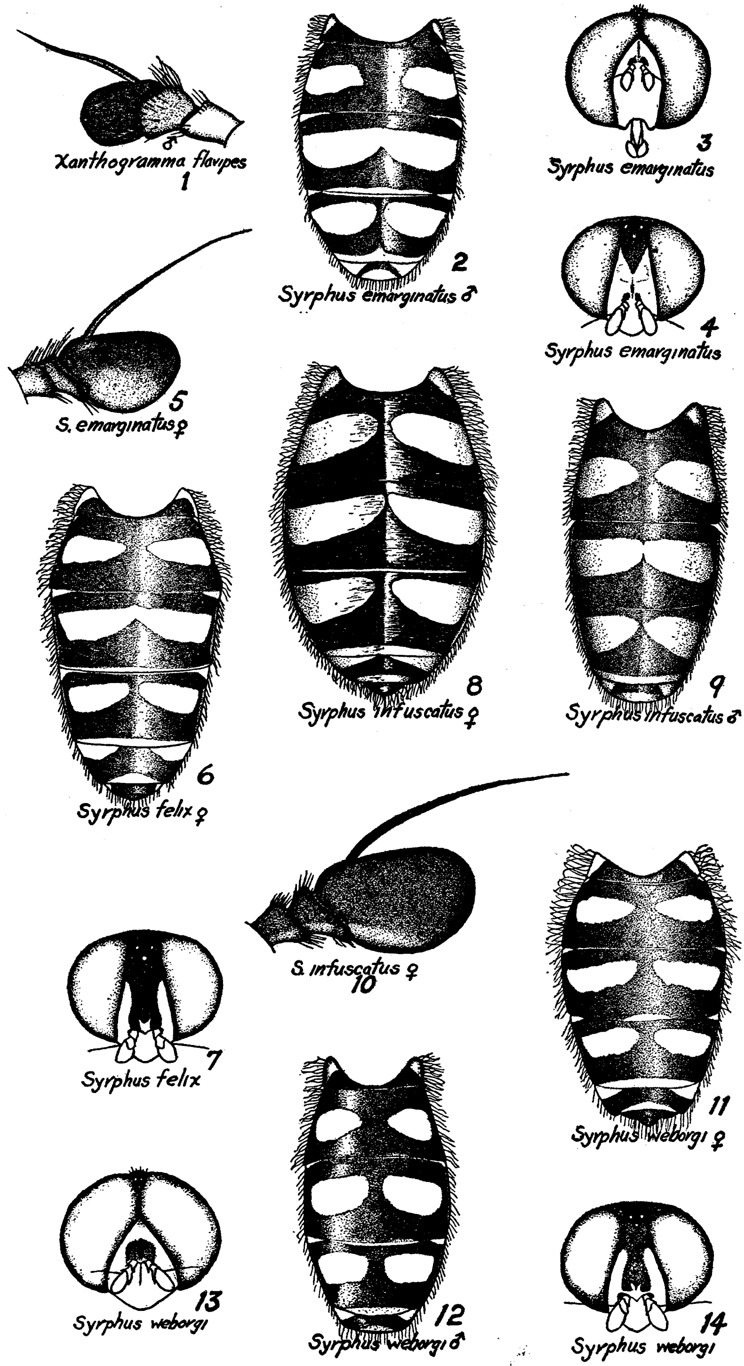
FIG. 1. *Xanthogramma flavipes,* antenna of male.
FIG. 2. *Syrphus emarginatus,* abdominal pattern of male.
FIG. 3. *Syrphus emarginatus,* front view of head of male.
FIG. 4. *Syrphus emarginatus,* front view of head of female.
FIG. 5. *Syrphus emarginatus,* antenna of female.
FIG. 6. *Syrphus felix,* abdominal pattern of female.
FIG. 7. *Syrphus felix,* front view of head of female.
FIG. 8. ***Syrphus infuscatus,*** n. sp., abdominal pattern of female.
FIG. 9. *Syrphus infuscatus,* abdominal pattern of male.
FIG. 10. *Syrphus infuscatus,* antenna of female.
FIG. 11. ***Syrphus weborgi,*** n. sp., abdominal pattern of female.
FIG. 12. *Syrphus weborgi,* abdominal pattern of male.
FIG. 13. *Syrphus weborgi,* front view of head of male.
FIG. 14. *Syrphus weborgi,* front view of head of female.

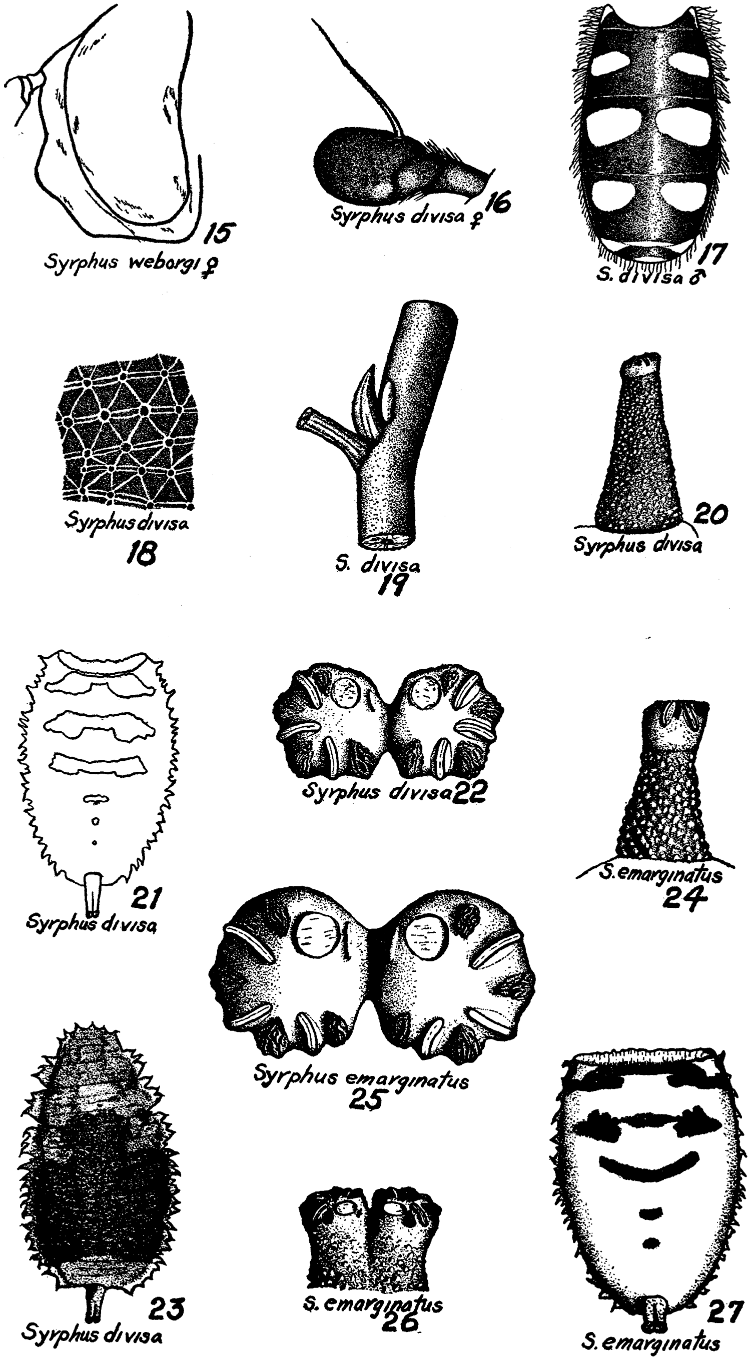
PLATE VI

FIG. 15. ***Syrphus weborgi,*** profile of head of female.
FIG. 16. *Syrphus divisa,* antenna of female.
FIG. 17. *Syrphus divisa,* abdominal pattern of male.
FIG. 18. *Syrphus divisa,* showing egg chorion pattern, greatly enlarged.
FIG. 19. *Syrphus divisa,* showing position of egg on aspen twig.

FIG. 20. *Syrphus divisa,* side view of posterior respiratory appendage.
FIG. 21. *Syrphus divisa,* empty puparium.
FIG. 22. *Syrphus divisa,* surface view of spiracular field, showing the three pairs of spiracles, the circular plate, and the roughened areas between the spiracles.
FIG. 23. *Syrphus divisa,* larva showing the serrated edges and the orange-colored band, shown as the dark area on the drawing.
FIG. 24. *Syrphus emarginatus,* side view of the posterior respiratory appendage. Compare with figure 20.
FIG. 25. *Syrphus emarginatus,* surface view of spiracular field, compare with figure 22.
FIG. 26. *Syrphus emarginatus,* dorsal view of the tip of the posterior respiratory appendage.
FIG. 27. *Syrphus emarginatus,* empty puparium.

TRANS. WIS. ACAD., VOL. 26 PLATE V




15
Syrphus weborgi ♀
Syrphus divisa ♀ 16
17
S. divisa ♂
Syrphus divisa
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S. divisa
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Syrphus divisa
21
Syrphus divisa
Syrphus divisa 22
S. emarginatus
24
Syrphus emarginatus
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23
Syrphus divisa
S. emarginatus
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27
S. emarginatus

PRELIMINARY LIST OF THE HYDRACARINA OF WISCONSIN

I. THE RED MITES

RUTH MARSHALL

The interest of students of fresh water biology in the water mites makes it desirable to have lists of determined species for different regions in America. Such a list is now being compiled for Wisconsin from the data and collections in the writer's possession. This list when completed will probably be equally applicable to the entire upper Mississippi basin and southern Canada. The present paper, which is the beginning of a check list, records fourteen species belonging to the group of "red mites". Data on distribution and one or more figures are given for each species. In this paper synopses are included only in the case of the two new species to be described. The figures, it is hoped, will be sufficient in most cases to enable the student who has some general knowledge of the group to make identifications for himself. The accompanying bibliography gives the papers where full or original descriptions may be found. For the determination of the genera the reader is referred to Dr. Wolcott's *A Review of the Genera of the Water Mites* or his article on the group in Ward & Whipple's *Fresh Water Biology.* For a more recent and fuller account of the genera and a description of the cosmopolitan species, Soar & Williamson's *British Hydracarina* should be consulted. In the grouping of the genera the writer has followed Dr. Koenike's article on Hydracarina in *Tierwelt Mitteleuropas.*

The red water mites form the super-family *Limnocharae* which is divided into eight families, all but one of which are known to be represented in the Wisconsin fauna. They are common in shallow waters and are the simplest members of the group of the Hydracarina (which may be regarded as forming a suborder). They are usually large, oval mites, red or orange in color; the skin is soft, covered with papillae of different kinds, and often develops dorsal plates. The double eyes of each side lie on chitinized capsules; an unpaired eye may be present. The epimera (leg plates) are in four groups, often considerably separated. The genital area is near the epimera; the character of the plates and acetabula of this region are important in distinguishing the genera. Sexual dimorphism is not very marked. The five-jointed palpi are sometimes chelate. The legs (of six segments each) are short, end in claws and bear numeous bristles and sometimes swimming hairs.

Limnochares aquaticus (L.)

Pl. VII, fig. 1–3.

This common mite, one of the largest, is the only species recorded for the genus. It is widely distributed over Europe and has been found also in British Columbia, Ontario, Minnesota, Michigan, Indiana, and New York. In Wisconsin it has been found in Catfish Lake (Vilas County), in ponds near Cable and Green Bay, in Storr Lake (near Milton), in Fox Lake and the Waupaca Chain-o'-Lakes.

Eylais desecta Koen.

Pl. VII, fig. 13, 14.

The highly variable character of the eye plate upon which so far the determination of the species of this large genus has been largely based, together with the uncertainty of what should be regarded as specific characters, make identifications here very difficult. This is the only species which has been determined with some degree of certainty; other species are undoubtedly present in the state. It has been recognized in material from Ontario and Michigan; in Wisconsin specimens have been found in pools near Madison, Green Bay, Green Lake, Jordan Lake (Adams County), in Lake Koshkonong, Bass Lake (Waupaca), Little John (Vilas County) and in the Wisconsin River near Kilbourn.

Protzia ovata n. sp.

Pl. VII, fig. 9–12.

The body is obovate, slightly shouldered. The largest specimen found measured 1.20 mm. The surface of the body has conspicuous papillae, rounded or slightly pointed. The double eyes of each side are large and lie on distinct plates. The epimera are typical of the genus. The genital area is extensive and lies between the epimeral groups. The genital plates are inconspicuous; they are surrounded by large oval stipitate irregularly placed acetabula, of which there are about thirty in the female, with numerous long hairs among them. The capitulum is large and broad, extending over the body margin. The palpi are short and bear short hairs; the distal projection of segment four is conspicuous. The legs are short, resembling those of *P. eximia* Protz, the type species; they are without swimming hairs and end in serrated spoon-shaped claws.

The new species appears to resemble most closely *P. caucasica* Sok., found in Russia; the stalked acetubula, however, are more numerous. The shape of the body together with details of the genital area distinguish this species from others of the genus described.

Five individuals were found in Green Lake by Professor C. Juday. All but one appear to be females; the remaining one, probably a young male, was not sufficiently well preserved to permit of a determination. This is the first described species of the genus Protzia to be reported for North America.

Hydrachna crenulata Mar.

Pl. VIII, fig. 28.

This species has been found in but two localities: in Fox Lake and in a pool near Oxford.

Hydrachna rotunda Mar.

Pl. VIII, fig. 23.

Specimens of this species have been found in Lake Winnebago and in pools near Green Bay, Green Lake and Jordan Lake. The small dorsal plates are irregular and variable.

Hydrachna canadensis Mar.

Pl. VIII, fig. 24.

As in the last species, the dorsal plates show a considerable degree of variability. Specimens have been found in Lake Winnebago and Trout Lake.

Hydrachna bilunata n. sp.

Pl. VIII, fig. 26, 27.

The body is hemispherical and may attain a length of 3.00 mm. The surface shows very small low papillae. The color is bright red. A small irregularly lunate plate lies just back of each eye plate; still farther back are two irregular, somewhat oblong plates or bars, all of these structures variable in shape. The fourth pair of epimera show a prominent rounded projection on the inner posterior corner, these plates thus largely surrounding the female genital area. The new species resembles *H. amplexa* Koen., found in Madagascar. The male is unknown.

Specimens have been found in British Columbia and in Wisconsin in pools near Green Lake, Trout Lake and Jordan Lake.

Hydrachna schneideri americana Mar.

Pl. VIII, fig. 21, 22.

The large plate posterior to the eyes is variable in outline as it is in the parent species. The male of this variety has now been identified; the genital area is somewhat cordate, broader than in *H. schneideri* Koen.

The species has been found in Alberta, North Dakota and Maine. In Wisconsin it has been found in Lake Winnebago, Trout Lake pool, ponds at Big Spring (Adams County), Mirror Lake and the Wisconsin River near Kilbourn.

Hydrachna magniscutata Mar.

Pl. VIII, fig. 25.

This species has been found in Indiana, New Jersey and Michigan. In Wisconsin it is known for Lake Winnebago, Fox Lake, Lake Pewaukee, Mirror Lake, Silver and Ballard lakes near Trout Lake, and in pools near Green Lake and Burlington.

Pseudosperchon verrucosus (Protz)

Pl. VIII, fig. 15–18.

Much interest attaches to the finding of this cosmopolitan species, the first record for the New World to the writer's knowledge. It has been known heretofore for Europe and northern Africa. Two specimens, each measuring 0.50 mm., were found in Green Lake by Professor Juday. They have been compared with identified material from the collection of the late Dr. Koenike and also with specimens kindly sent to the writer by Dr. Viets. There seems to be no doubt of the identification. Drawings are submitted in confirmation of this finding.

Hydryphantes ruber (deGeer)
Pl. VII, fig. 5, 6.

This species, common throughout Europe, has been found in a pool near Jordan Lake. It has also been found in Illinois and Ohio and is reported by Dr. Nathan Banks for Northwest Territory.

Hydryphantes tenuabilis Mar.
Pl. VII, fig. 4.

This common species has been found in Lakes Winnebago, Delavan, Storr and Mason; and in pools and ponds near lakes Jordan, Beulah, Geneva and Waubesa. It also occurs in Iowa, Michigan and Ohio.

Hydryphantes multiporus Mar.
Pl. VII, fig. 7, 8.

This is a rare species and has been found only in Goose Pond near Jordan Lake.

Diplodontus despiciens (Müll.)
Pl. VIII, fig. 19, 20.

This is one of the commonest and most widely distributed species of water mites. It has been found in or near the following lakes and ponds: Lauderdale, Beulah, Burlington, Delavan, Whitewater, Wingra, Fox, Storr, Buffalo (Waupaca), Big Spring, Silver (Portage), Mason, Oxford, Jordan, Mirror, Spooner, Cable, Otter (Eagle River), and ten lakes in Vilas County. It has also been found in New York, New Jersey, South Carolina, Michigan, Iowa, North Dakota, Ontario, British Columbia, Cuba and Panama. It has been reported for all parts of Europe, for South America, Asia and Africa.

ROCKFORD COLLEGE,
JANUARY 1, 1931.

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EXPLANATION OF THE PLATES

PLATE VII

1. *Limnochares aquaticus*, dorsal eye plate
2. *Limnochares aquaticus*, ventral plates (left 3rd and 4th epimera omitted)
3. *Limnochares aquaticus*, dorsal view
4. *Hydryphantes tenuabilis*, dorsal plate
5. *Hydryphantes ruber*, ventral view
6. *Hydryphantes ruber*, dorsal plate
7. *Hydryphantes multiporus*, dorsal plate
8. *Hydryphantes multiporus*, genital area
9. *Protzia ovata*, capitulum and right palpus
10. *Protzia ovata*, ventral surface, female
11. *Protzia ovata*, end of leg IV

12. *Protzia ovata,* eye region
13. *Eylais desecta,* dorsal surface
14. *Eylais desecta,* eye plate

PLATE VIII

15. *Pseudosperchon verrucosus,* dorsal view
16. *Pseudosperchon verrucosus,* detail of a tubercule
17. *Pseudosperchon verrucosus,* right palpus
18. *Pseudosperchon verrucosus,* ventral surface
19. *Diplodontus despiciens,* dorsal view
20. *Diplodontus despiciens,* ventral plates, young male
21. *Hydrachna schneideri americana,* male genital area
22. *Hydrachna schneideri americana,* dorsal plate
23. *Hydrachna rotunda,* anterior dorsal region
24. *Hydrachna canadensis,* anterior dorsal region
25. *Hydrachna magniscutata,* dorsal view
26. *Hydrachna bilunata,* anterior dorsal region
27. *Hydrachna bilunata,* ventral plates, female
28. *Hydrachna crenulata,* anterior dorsal region

 PLATE VII

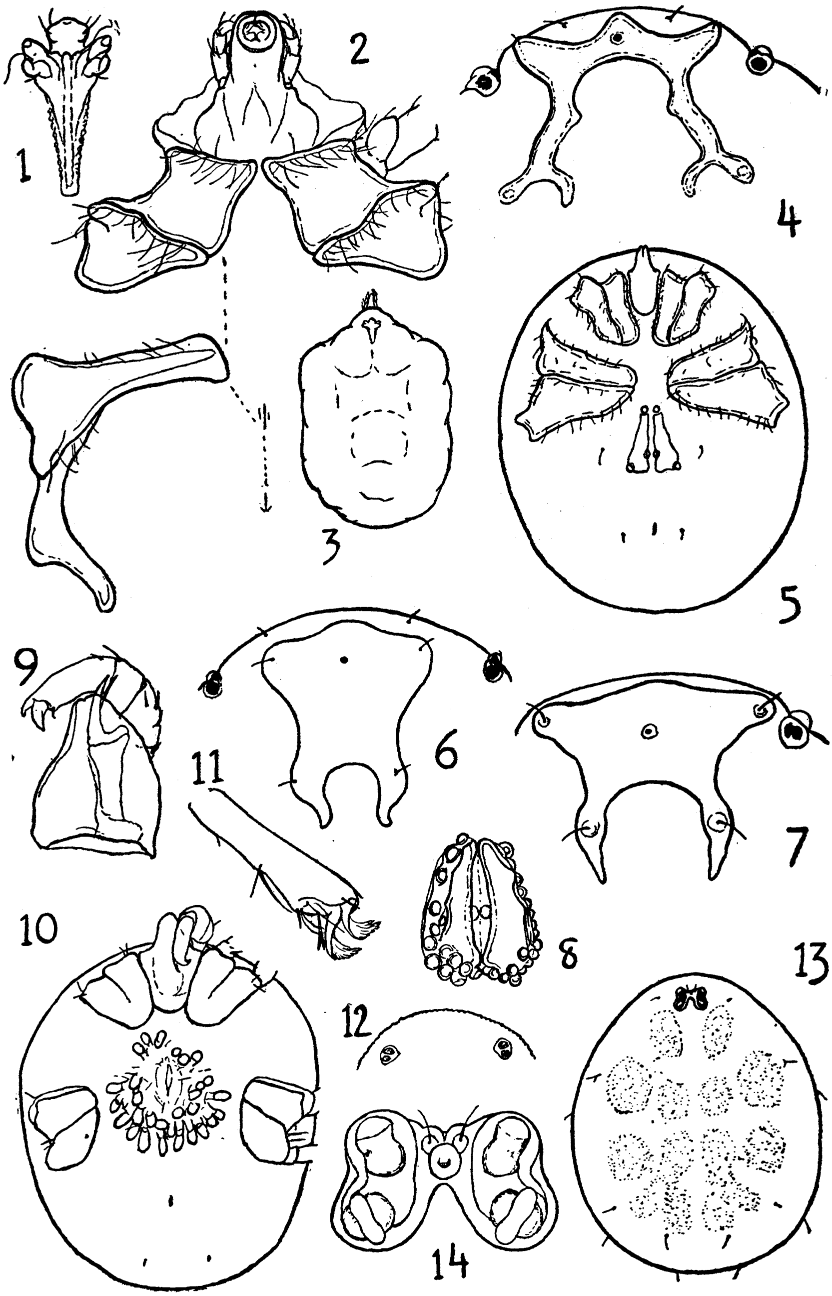

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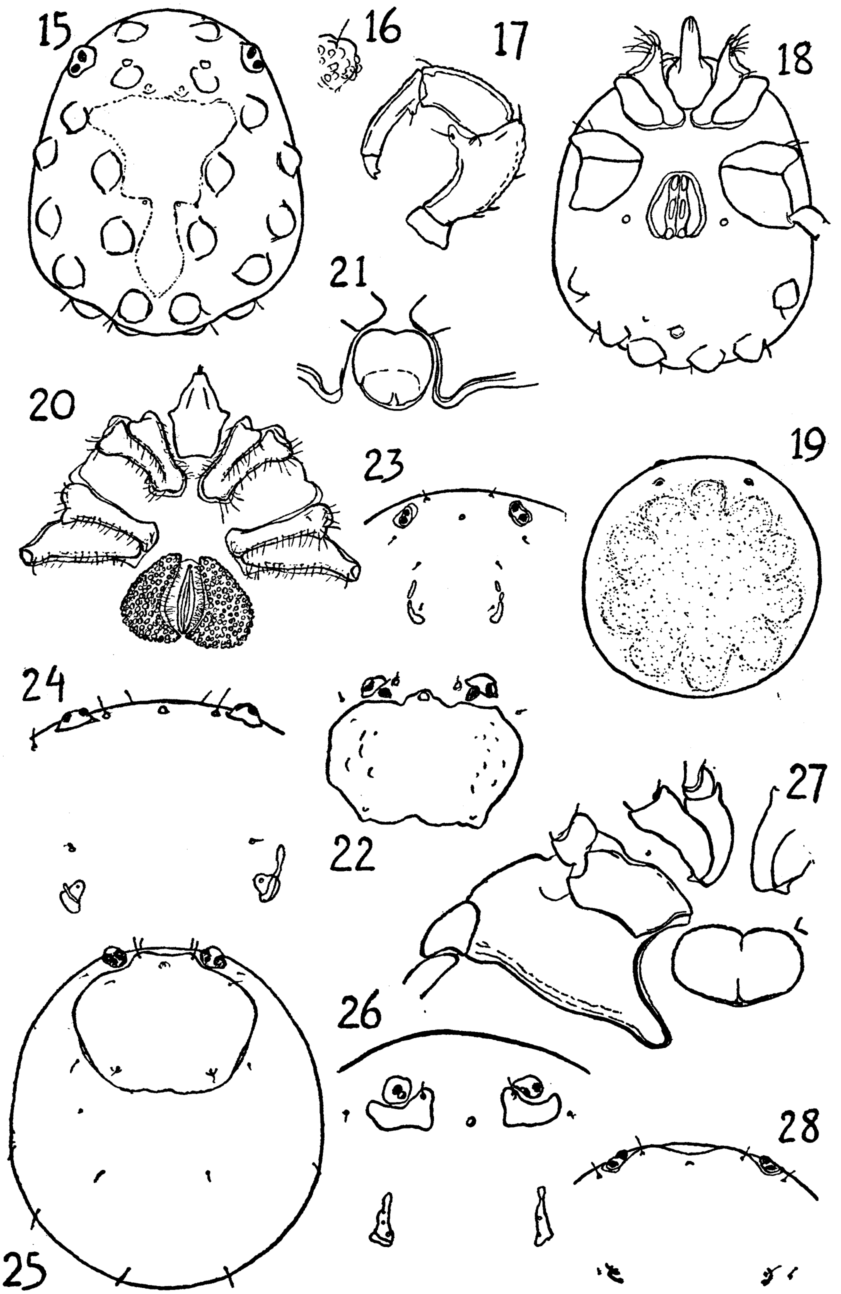
PLATE VIII



WISCONSIN HERPETOLOGICAL NOTES

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In order that our knowledge of the herpetological fauna of Wisconsin may be maintained up to date, there is submitted herewith a detailed list of such information on this subject as has come to the attention of the writer during the past year.

This list of reptiles and amphibians represents chiefly additional distributional data acquired since our recent publication (Pope and Dickinson 1928, Pope 1928 and 1930).

The items composing this list comprise principally specimens collected or received during the year 1929 as well as certain species indicated in publications or observed in that year. A few items representing localities inadvertently omitted in the previous bulletin and some withheld pending positive identification or reidentification have also been inserted in this article. The observations cited are principally those made by Dr. A. I. Ortenburger while he was connected with the Wisconsin Geological and Natural History Survey in 1918.

The following species of Wisconsin amphibians and reptiles are hereby reported from counties not indicated in the publications mentioned above. It is believed that these records constitute new distributional data:

A. Species that are represented by actual preserved specimens in the possession of the Milwaukee Museum.

AMPHIBIA

Mudpuppy *(Necturus maculosus)*.
Jefferson County. Milwaukee Museum. Cat. No. 2319.
Collected by Haywood Rose at Lake Palmyra on May 5, 1929. Living when received on May 7.

Common Newt *(Triturus viridescens viridescens)*.
Vernon County. Milwaukee Museum. Cat. No. 2330.
Collected by W. R. Spellum at Bad Axe River on June 2, 1929. Length 2½ inches.

Spotted Salamander *(Ambystoma maculatum).*
Milwaukee County. Milwaukee Museum. Cat. No. 2341 (2 spec.).
Collected by W. V. Tyrrell while digging a well at North Milwaukee. Living when received by museum Dec. 6, 1929 and held in captivity until March 1 and March 16, 1930. Museum photograph No. 405277.

American Toad *(Bufo americanus).*
Marquette County. Milwaukee Museum. Cat. No. 1831.
A dried and inflated skin received from William Menge Aug. 31, 1920.

Swamp Cricket Frog *(Pseudacris feriarum).*
Vernon County. Milwaukee Museum. Cat. No. 2331.
Collected by T. E. B. Pope at Stoddard on June 5, 1929.

Spring-peeper *(Hyla crucifer).*
Dane County. Milwaukee Museum. Cat. No. 2340.
Collected by W. E. Dickinson at Madison on Sept. 30, 1929.

Reptilia

Eastern Ring-necked Snake *(Diadophis punctatus edwardsii).*
Langlade County. Milwaukee Museum. Cat. No. 2334.
Collected by Ulrich Dernehl at Elcho. Received Aug. 19, 1929. Museum photographs 405268-405269.

Hog-nosed Snake *(Heterodon contortrix).*
Waushara County. Milwaukee Museum. Cat. No. 2322.
Collected by Dr. G. H. Bush of Ripon at White River and received alive on May 29, 1929. Young specimen. This species was previously cited from this county by observation only.

Smooth Green Snake *(Liopeltis vernalis).*
Sauk County. Milwaukee Museum. Cat. No. 2337.
Collected by E. D. Ochsner at Prairie du Sac on Aug. 23, 1929.

Fox Snake *(Elaphe vulpina).*
Forest County. Milwaukee Museum., Cat., No., 2336.
Collected by Norman Seeger at Stone Lake. Received Sept. 3, 1929.

Yellow-bellied King Snake *(Lampropeltis calligaster).*
Milwaukee County. Milwaukee Museum. Cat. No. 1833.
Collected by Miss Ruth Ward at Milwaukee on July 20,

1920. Kept alive at the museum on exhibition until Oct. 10, 1920, then killed and skinned. A cast skin of this specimen also on hand. Length 51 inches. This is the first record we have of the species within the state although it had been anticipated.

De Kay's Snake *(Storeria dekayi).*

Washington County. Milwaukee Museum. Cat. No. 1671.
Collected by Rose Miller at West Bend in August 1911. Length 105 mm.

Red-bellied Snake *(Storeria occipitomaculata).*

Wood County. Milwaukee Museum. Cat. No. 2318.
Collected by Guy Nash at Wisconsin Rapids on April 23, 1929.

Milwaukee County. Milwaukee Museum. Cat. No. 2339.
Collected by Harry A. Miller at Whitefish Bay on Nov. 10, 1929 and received alive by the museum.

Milwaukee County. Milwaukee Museum. Cat. Nos. 738-1594 1667-1668-1669-1672-1782-1783 (8 spec.) collected by various persons.

Butler's Garter Snake *(Thamnophis butleri).*

Washington County. Milwaukee Museum. Cat. No. 996.
Collected by Dr. S. Graenicher at Cedar Lake in August 1909.

Common Garter Snake *(Thamnophis sirtalis sirtalis).*

Sauk County. Milwaukee Museum. Cat. No. 2022.
Collected by W. E. Dickinson at Prairie du Sac on July 11, 1926. Length 19 inches.

Sauk County. Milwaukee Museum. Cat. No. 2110.
Collected by E. C. Keitel at Merrimack. Received Sept. 18, 1926. Length 36 inches.

Sauk County. Milwaukee Museum. Cat. Nos. 2144-2151 (8 spec.).
Collected by E. C. Keitel at Merrimack and received alive by the museum on June 15, 1927. Lengths ranging from 27 to 39 inches.

Bell's Turtle *(Chrysemys marginata bellii).*

Vernon County. Milwaukee Museum. Cat. Nos. 2323-2324 (2 spec.).
Collected by T. E. B. Pope at Stoddard on June 5, 1929.

B. Species that are listed or mentioned in recognized scientific publications. It is assumed that actual specimens to support such data are deposited in institutions.

These consist of a list of amphibians and reptiles of Waukesha County by Alvin R. Cahn (Cahn 1929). Only those species not indicated in the Milwaukee Museum bulletin as occurring in this county are included in the following:

AMPHIBIA

Common Newt *(Triturus viridescens viridescens).*
Spotted Salamander *(Ambystoma maculatum).*
Marbled Salamander *(Ambystoma opacum).*
Tiger Salamander *(Ambystoma tigrinum).*
Four-toed Salamander *(Hemidactylium scutatum).*
Red-backed Salamander *(Plethodon cinereus).*
Slimy Salamander *(Plethodon glutinosus).*
Swamp Tree Frog *(Pseudacris triseriata).*
Spring-peeper *(Hyla crucifer).*
Northern Wood Frog *(Rana cantabrigensis).*
Pickerel Frog *(Rana palustris).*

REPTILIA

Blue-tailed Skink *(Eumeces fasciatus).*
Eastern Ring-necked Snake *(Diadophis punctatus edwardsii).*
Hog-nosed Snake *(Heterodon contortrix).*
Blue Racer *(Coluber constrictor flaviventris).*
Fox Snake *(Elaphe vulpina).*
Bull Snake *(Pituophis sayi).*
Kirtland's Water Snake *(Natrix kirtlandii).*
Queen Snake *(Natrix septemvittata).*
Common Water Snake *(Natrix sipedon sipedon).*
Western Ribbon Snake *(Thamnophis proximus).*
Plains Garter Snake *(Thamnophis radix).*
Spotted Turtle *(Clemmys guttata).*
Common Box Turtle *(Terrapene carolina carolina).*

C. Species that have been observed by reliable persons.

Amphibia

American Toad *(Bufo americanus)*.

Portage County. Observed by Dr. A. I. Ortenburger at Stevens Point on July 17, 18, 19, 1918.

Winnebago County. Observed by T. E. B. Pope and W. E. Dickinson on low swampy land adjoining the state fish hatchery at Oshkosh on May 25, 1927. Many specimens were mating.

Swamp Tree Frog *(Pseudacris triseriata)*.

Dunn County. Observed by Dr. A. I. Ortenburger at Meridean on Aug. 14, 1918.

Northern Wood Frog *(Rana cantabrigensis)*.

Sauk County. Observed by Dr. A. I. Ortenburger at Kilbourn on Aug. 23, 1918. (7 spec.).

Mink Frog *(Rana septentrionalis)*.

Marathon County. Observed by Dr. A. I. Ortenburger at Rib Hill on July 3, 1918.

Portage County. Observed by Dr. A. I. Ortenburger at Plover River near Stevens Point on July 19, 1918.

Bullfrog *(Rana catesbeiana)*.

Marathon County. Observed by Dr. A. I. Ortenburger at Rib Hill on July 10, 1918.

Portage County. Observed by Dr. A. I. Ortenburger at Plover River near Stevens Point on July 17, 18, 1918. (10 spec.).

Clark County. Observed by Dr. A. I. Ortenburger at Withee, Black River, on July 22, 1918 (2 spec., male and female), also on July 24, 1918.

Washburn County. Observed by Dr. A. I. Ortenburger at Long Lake on Aug. 3, 1918 (male spec.).

Walworth County. Observed by Dr. A. I. Ortenburger at Whitewater on Sept. 7, 1918.

Reptilia

Smooth Green Snake *(Liopeltis vernalis)*.

Portage County. Observed by Dr. A. I. Ortenburger at Stevens Point on July 20, 1918 on a sandy road; female.

Plains Garter Snake *(Thamnophis radix).*

Columbia County. Observed by Dr. A. I. Ortenburger at Lodi on Sept. 5, 1918. (3 spec.).

Sauk County. Observed by Dr. A. I. Ortenburger at Devils Lake on Aug. 25, 1918. (2 spec.).

Vilas County. Observed by Dr. A. I. Ortenburger at St. Germain Creek, Sayner, on June 23-24, 1918. (3 spec.).

Blanding's Turtle *(Emys blandingii).*

Kenosha County. Observed by W. E. Dickinson on road, April 7, 1929. Specimen badly damaged.

Western Painted Turtle *(Chrysemys marginata marginata).*

Dunn County. Observed by Dr. A. I. Ortenburger at Chippewa River, Meridean, on Aug. 15, 1918.

Bell's Turtle *(Chrysemys marginata bellii).*

Kenosha County. Observed by W. E. Dickinson on road, April 7, 1929. Specimen badly crushed by auto.

Special mention may now be made of certain species in the possession of the Milwaukee Museum that represent new localities, are rather uncommon, or are entirely new additions to the state fauna.

Four-toed Salamander *(Hemidactylium scutatum).* In the article published last year on the herpetology of the state it was shown that this small salamander was taken in Vernon County where it was reported by W. R. Spellum to be "common and widely spread over the county." Heretofore, it had only been taken at Racine in early days by Dr. P. R. Hoy and recently in Winnebago County by Howard E. Reed. Of interest then may be the collecting by Mr. Spellum and the writer of fully a dozen more specimens in the valley of the Bad Axe River, Vernon County, on June 2, 1929. Five of these specimens are preserved at the Milwaukee Museum as Cat. No. 2329. These specimens were easily found under both boulders and logs on rather dry hillsides. This fact is noted because the species has been claimed also to inhabit sphagnum swamps. Cahn now reports it from Waukesha County. Thus the prophecy of the probable state-wide distribution of this formerly little-known amphibian is now being slowly realized.

Swamp Cricket Frog *(Pseudacris feriarum).* As shown by the above records, the Milwaukee Museum specimen, Cat. No. 2331, represents a new distributional area for the species. This specimen was taken on the bank of the Mississippi River while the only other known specimens are those listed by the University of Wisconsin from Adams County in the central part of the state in the same general latitude.

Yellow-bellied King Snake *(Lampropeltis calligaster)*. The inclusion of this snake in the ophidian fauna of Wisconsin has been based on the recorded range of the species by Stejneger and Barbour (1923) and which has been cited as, "Illinois and Wisconsin to Texas". The recent reidentification of the Milwaukee Museum specimen, Cat. No. 1833, thus definitely affirms the existence of this serpent within the state. In this connection it may be stated that this specimen was compared with a specimen of the same species, identified and donated by Dr. F. N. Blanchard of the University of Michigan, collected at Haverhill, Kansas, and now deposited in the Milwaukee Museum as Cat. No. 2167. On August 29, 1929 another specimen, Milwaukee Museum Cat. No. 2335, was found on a box car of lumber at Milwaukee consigned to the Pagel Lumber Company.

Western Diamond-back Rattlesnake *(Crotalus atrox atrox)*. Adverting to Milwaukee Museum specimen, Cat. No. 2293, of this species, which was announced and discussed in both the Milwaukee Museum Yearbook and Wisconsin Academy Transactions (Pope 1928 and 1930) it will be recalled that, concerning the method of its introduction into the state, the following was stated, "In answer to such inquiries———we can only conjecture, hoping that later investigations may reveal definite information. Its migration into Wisconsin probably followed up the Mississippi River———. Then again, it is not at all improbable that the first specimen, or specimens, in the State may have been brought into Wisconsin and escaped from captivity."

This latter theory (that of the escape of introduced specimens) appears at present writing to be our best solution of the problem. On Oct. 4, 1929, Mr. L. C. Stuart of the Museum of Zoology of the University of Michigan, wrote the writer as follows: "While working there (Wisconsin) several summers ago I heard of another report which might prove of interest to you. It seems that a number of years ago several specimens escaped from a circus in the vicinity of Pittsville in Wood County. It is still rumored that a colony of them have become established along a creek (Babcock Creek, I believe) a few miles to the west". Dr. L. M. Klauber of the Zoological Society of San Diego, California, says in a letter of Sept 30, 1929, "I cannot but believe that the introduction of these snakes into Wisconsin must have been accidental rather than a natural extension of the range." And again, on Nov. 26, 1929, after learning of the statement of Mr. Stuart cited above, "I do not at all question the presence of this species in your state, for your description and the photographs are quite definite on this point. I think the explanation that the nucleus of this colony escaped from a circus is quite probably correct. We hear of specimens escaping in this manner rather frequently, although it is of course true that seldom do a sufficient number get away to form a new colony."

While no actual specimens of the Western Diamond-back Rattlesnake have been acquired by the Milwaukee Museum since the acquisition of Cat. No. 2293, it may be of interest to state that the writer has heard several more rumors concerning their presence in the state. Furthermore, Mr. Huron H. Smith, Curator of Botany in the Milwaukee Museum, has submitted notes to the effect that while engaged in field-work that Tenus Tuttrup (formerly his assistant) and himself saw a Diamond-back rattler near Monument Rock south of Liberty Pole, Vernon County, U. S. Highway No. 61, on July 14, 1922. It will be noted that Monument Rock is within a mile of Hogback Hill where three specimens, including a young one, were reported under affidavit as killed in the latter part of August 1928. Still more interesting, it will be noted that this observation by Mr. Smith was made on a date six years previously, thus confirming the assertion that this serpent had become established in this state and for a longer period of time than perhaps we realized. Mr. Smith says that this specimen of snake was only about fifteen feet distant from him at the time of observation and that he plainly saw the prominent white stripes on the side of the snake's head that distinguishes this species at sight from the common Banded Rattlesnake *(Crotalus horridus)*. This specimen was about six feet long.

Now as to the statement of Mr. Stuart mentioned above. Babcock Creek is in the vicinity of Babcock in the southwestern part of Wood County, about sixty miles distant airline from Viroqua and northeast from the same. Quoting Mr. Smith again we find the Winnebago Indians familiar with this serpent in this locality when he says, "During the latter part of August 1928, I heard a rumor of the appearance of the Diamond-back Rattler from some Winnebago Indian friends of mine who were also informants in my field work done among them that summer It came about thru a trip when I took George Monegar, a chief and medicine man and his wife over to collect a few remedies that did not grow near their home. We went to Nekoosa and south of there to some sand hills. Among these remedies was one for a certain kind of rattlesnake, which they called the 'King of the Rattlesnakes' and which was different from the usual small kind said to infest Rabbit Hill in northern Adams County. They told me that this kind was found around Babcock Creek, in the vicinity of Babcock, in the southwestern part of Wood County. I was often around Babcock, but did not get to see the snakes. Further confirmation was given to the presence of this snake by Ray White and Fred Mallory, both Winnebago Indians. Their opinion was that the snakes were not common and had come in possibly eight years ago."

Thus it appears that, if the escape of the snakes from a circus near Pittsville be confirmed, some members of the Babcock Creek colony must have found their way to Vernon County by passing southwesterly through the northern portion of Juneau County and diagonally through Monroe County.

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LIMNOLOGICAL STUDIES OF LAKE WINGRA

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Very little work has been attemped in the way of limnological studies on small, shallow American lakes in which little or no stratification occurs. This situation led in October 1925 to the beginning of a study of Lake Wingra by Dr. A. H. Wiebe. He continued his studies until June 1926, after which they were taken up by Dr. Stillman Wright and the present authors, according to the following schedule:

June 1926 to September 1926, B. P. Domogalla.
September 1926 to June 1927, S. Wright.
June 1927 to January 1928, B. P. Domogalla.
February 1928 to January 1930, W. L. Tressler.

THE LAKE

Within a few miles of the city of Madison, Wisconsin, there are five lakes. Four of these, Lakes Mendota, Monona, Waubesa and Kegonsa, are in a chain through which the Yahara river flows on its way to the Rock River, a tributary of the Mississippi. The city of Madison lies for the most part between and on the shores of Lakes Mendota and Monona. Lake Wingra adjoins the city on the southwest. Juday (1914) gives the following account of the lake:

"Lake Wingra is a small, shallow body of water which lies a short distance west of lake Monona; its waters reach the latter through Murphy creek which has recently been dredged and made into a canal. The name Wingra is that which was applied to this lake by the Winnebago Indians who formerly occupied this portion of Wisconsin. The names signifies *dead* and locally this body of water is frequently called "Dead" Lake. In reality, however, this lake is not dead yet but has reached an advanced stage in its life history, and this fact doubtless accounts for the application of this name to it. The maximum depth is 4.25 m. (14 ft.) and by far the greatest portion does not exceed 3 m. in depth.

"*Shores.* The immediate shores of the entire lake are swampy and marshy. This low margin varies in width from only a few meters in some places to a kilometer or more at other places. At two points on the south side and along practically all of the north side the swampy margin is not very wide and back of this zone the shores rise rather abruptly to a height of 8 m. to 10 m. (26 ft. to 33 ft.) above the level of the lake. At the western end the low margin is more extensive and the rise to higher ground beyond is more gradual. The most extensive marsh and swamp areas are located along the eastern and southeastern portions of the lake. The low shores support a luxuriant growth of vegetation and an abundant growth of the larger aquatic plants is also found in the shallow water along the margins of the lake.

"At the northeastern corner of the lake a small low island has been formed artifically by dredging and filling and the low portion of the shores at this point has also been raised by artificial filling. Extensive modifications by dredging and filling have also been made along the southern shore.

"There are large marl deposits both on the bottom of lake Wingra and along its margins. In some places these deposits reach a thickness of 8 m. to 9 m. (26 ft. to 30 ft.).

"*Sources of Water.* Two small streams enter lake Wingra, one at the west end and the other on the south side; the chief source of water consists of springs which are situated along the margin of the lake. There are two large springs on the south side of the lake and one on the north side together with a number of small ones on these two sides as well as at the west end. The outlet emerges from the lake at the northeastern corner."

Since this description was written there has been some rather extensive dredging and filling along the north and south shores, but the maximum depth of the lake has remained unchanged.

Pearse and Achtenberg (1920) give the following figures for Lake Wingra:

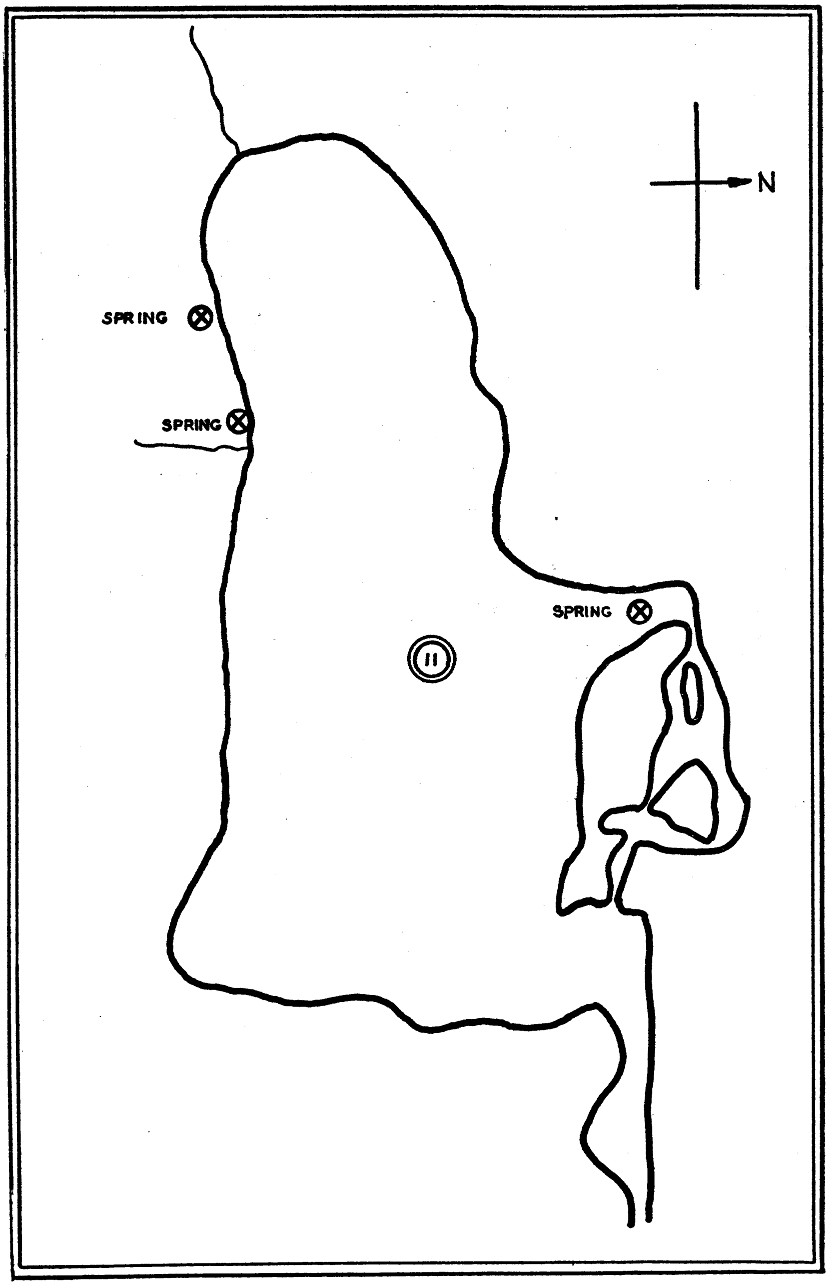

FIGURE 1. Outline map of Lake Wingra. The station where the water samples and plankton catches were taken is marked by the number 11.

Length	2.6 kilometers
Width	1.4 kilometers
Area	2.17 square kilometers
Volume	3,472,000 cubic meters
Maximum depth	4.25 meters
Mean depth	1.6 meters
Shore line	7.3 kilometers

There are no industrial plants located near the lake nor within some kilometers from it and there are few houses directly on the shores of the lake; consequently the amount of pollution is very small, to which the low figures for nitrates and chlorides bear witness.

METHODS

With few exceptions samples were taken from a single station, marked by the number 11 on the map (Fig. 1). At this station the depth was about 3.5 meters. From February through May 1928 samples were taken every two weeks, and subsequently every month throughout the year until January 15, 1930, the date of the last sample. The time of day at which the samples were taken varied from eight to eleven o'clock in the morning.

At each trip the following observations were taken: (1) the temperature of the water at the surface and at the bottom, (2) the transparency of the water, measured by the Secchi disc, and (3) the thickness of the ice and snow when present. The color of the water was determined by the standard platinum-cobalt scale of the United States Geological Survey. The conductivity was determined by means of a field instrument made by Evershed and Vignoles of London.

The chemical procedures followed were those recommended by the American Public Health Association (1925) or by Birge and Juday (1911). Quantitative determinations of dry weight and organic matter were made on the centrifuge plankton. The net plankton was secured by means of a vertical haul net. Two trips were made in the fall of 1929 to secure bottom samples from various parts of the lake with the Ekman dredge. From time to time three and one-half liter samples of water were evaporated and the residue dried and weighed. These samples were later analyzed by the chemists of the Wisconsin Geological and Natural History Survey for organic carbon, calcium and silicon.

The entire investigation was made under the guidance of Professor Chancey Juday, whose help and advice the authors gratefully acknowledge. Thanks are also due Dr. W. D. Stovall and Dr. M. S. Nichols for permission to use the laboratories of the Wisconsin State Laboratory of Hygiene, where much of the chemical work was carried on.

TEMPERATURE

Due to the shallowness of the lake the bottom temperatures followed very closely those of the surface during the greater part of the year. From the curves in Figures 2 and 3 it may be noted that the maximum difference between surface and three and one-half meters for the two years occurred during the winter months. The divergence began in late November or early December after the ice had covered the lake, and increased to a maximum of about seven degrees in February or March. The bottom temperatures, always higher than the surface during the winter months, in April became lower as the air temperatures increased, and in general remained somewhat lower than the surface until late spring when the water of the lake was thoroughly mixed by the winds. The ice in 1928 melted on March 24, and was formed again in the fall on November 29. Accordingly, in that year the lake was covered with ice 116 days. In 1929 the ice went out on March 25 and formed again November 17, the lake being ice-covered for 129 days of the year.

Following the disappearance of the ice the winds stirred up the whole body of water and the temperature of surface and bottom became nearly uniform. It is a general rule with lakes that during calm periods after the overturn in the spring the surface warms up faster than the lower levels, so that the temperature there comes to exceed that at the bottom. This was apparently true in Lake Wingra in May of 1928 (see Fig. 2) and in April and May of 1929 (see Fig. 3). Conversely, following the mixing of the water, a cold period late in spring may lower the temperature of the surface water below that of the bottom. An apparent instance of this occurred in Lake Wingra

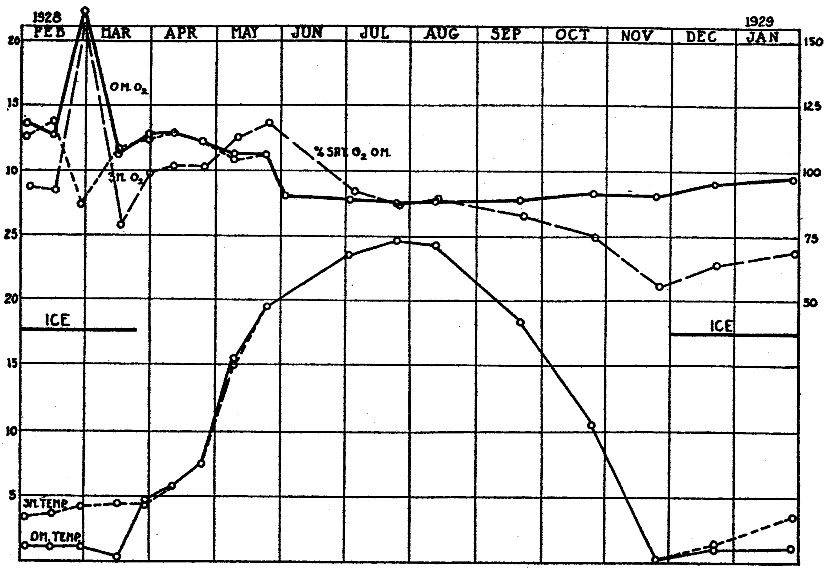

FIGURE 2. Temperature and oxygen curves 1928–1929. Temperatures are given in degrees Centigrade; oxygen in parts per million; oxygen saturation in per cent. 3M = three meters; OM = surface (zero meters).

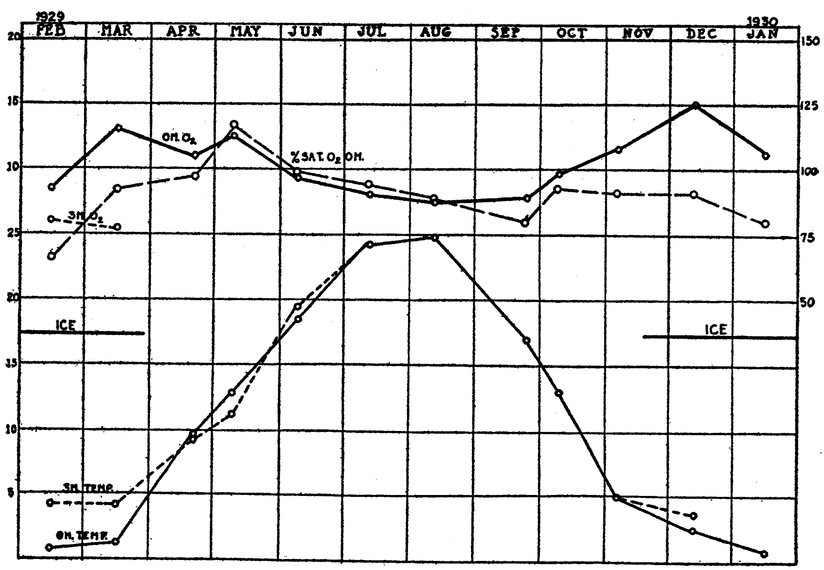

FIGURE 3. Temperature and oxygen curves 1929–1930. Temperatures are given in degrees Centigrade; oxygen in parts per million; oxygen saturation in per cent. 3M = three meters; OM = surface.

in June 1929 (see Fig. 3), when the bottom water was two and one-half degrees warmer than that of the surface.

The maximum temperature was observed during late July or early August, and from then on the temperature gradually fell until the ice formed in the late fall. The highest temperature recorded in the course of the study was 24.5; the lowest (just beneath the ice in winter) was 0.3. The maximum thickness if ice observed was 48 cm. (19 in.). The snow frequently reached a depth of 20 to 25 cm. The greatest depth recorded during the period of observation was 25 cm. (10 in.) on February 16, 1929.

TRANSPARENCY

The transparency as determined by the Secchi disc shows some correlation with the amount of organisms present in the water, since to a large extent the plankton shuts off the sun's rays from deeper penetration. When much plankton was present the transparency decreased, and when the amount was small a rise in the transparency was observed. The best illustrations were noted in the late fall and early winter of both years when the disc reading reached a maximum of two meters and the organic matter fell to one milligram per liter. In the summer months when the algae flourished, lower disc readings were the rule, and the same was true in the spring of 1928, when the large crop of diatoms brought the disc reading down to 0.5 meter.

Another factor which affected the transparency in Lake Wingra, as in other shallow lakes, was the action of the waves produced by high winds in summer, stirring up and distributing decomposition products and debris throughout the water mass. On a rough summer day the results obtained for organic matter were two or three times the maximum observed at other times. In the spring, moreover, the surface drainage brings in silt which lowers the transparency.

CONDUCTIVITY

The conductivity of the water was taken during the last part of the spring of 1929 and during the fall of that year. The results are expressed in terms of the reciprocal of the megohm resistance. On May 10, 1929 the conductivity was 302 and on

June 10, 318. Starting on October 9, 1929 when the conductivity was 292, it steadily rose to 394, observed on January 15, 1930. This led to a test of the springs which flow into the lake, with the result that the conductivity of the water flowing out of them was found to range between 475 and 500. In comparison with this, Lake Mendota seldom exceeds 300 units and in the lakes of the Trout Lake district of northern Wisconsin Birge and Juday (unpublished data) have found conductivities as low as 7 or 8 units. This is very near the average of ordinary distilled water (3-4 units). Lakes fed by rain water exclusively have lower conductivities than those fed by springs, whose water flows in contact with limestone deposits and is heavily impregnated with dissolved materials. Lake Wingra belongs to the latter class. Lake Mendota, although hardly more than two kilometers distant, shows conductivity readings about a hundred units lower than those of Wingra.

An analysis of the calcium in the water of Lake Wingra, made by the chemists of the Wisconsin Geological and Natural History Survey, gave the following results: on November 22, 1926 an average of 30.7 parts per million; on March 28, 1927, 40.1 at the surface and 39.8 at a depth of three meters; and on February 6, 1929 at the surface, 50.6 p.p.m.

Color

The color of the water was determined twice, and was found to correspond to color 18 on the platinum-cobalt scale. There is little in the water from the springs or from the drainage off the surrounding country to color the water.

Results of Chemical Analysis

Oxygen. The curves in figures 2 and 3 show the relation between oxygen and temperature. The oxygen reaches its highest point in the winter under the ice, both because the water will hold more at lower temperatures and because the ice keeps the water quiet and prevents the escape of oxygen produced in photosynthesis. With the rise of temperature in the spring and summer there is a corresponding decrease in the oxygen, so that the point of highest temperature coincides roughly with the minimum period for oxygen. With the decrease in temperature in the latter part of the summer the amount of oxygen gradually increases until the lake becomes covered with ice.

Thereafter a small increase was noted, until the ice and snow became thick enough to stop the light to such an extent that photosynthetic activity of the green plants was retarded. The curve in figures 2 and 3 which indicates percentage saturation shows that the surface water seldom holds all the oxygen that it could, and that only under unusual conditions (such as those to be described later) is there a saturation above 100 per cent. In general the greatest saturation was found in the spring, with a decrease thereafter until late in summer, when it rose again to a slightly higher figure in the winter. The peak in spring is due to the increased activity of the plants with the rise in insolation. The curve falls at the end of summer because the water becomes cooler and the plants have not increased their activity to keep pace with the greater oxygen capacity of the water.

Rather unusual conditions occurred in March 1928. The ice was then quite clear and there had been no snow for some time. The sun's rays were able to penetrate to a considerable depth, and enough oxygen was given off by the plants to cause a supersaturation near the surface. The maximum reading for oxygen was obtained at 2:30 p. m. on March 3, 1928, when 28.1 parts per million were found. This is 198 per cent saturation. Birge and Juday (1911) report as high as 364 per cent in other lakes observed by them.

Carbon Dioxide. Free carbon dioxide was found in Lake Wingra during the winter months of both years, beginning in late December or early January and continuing until the ice went out in the middle of March. During the spring and summer there was a deficiency of carbon dioxide, due to the activity of the aquatic plants. The bottom water always contained more free carbon dioxide than the surface water, due to the decomposition of materials on the bottom. This is evident from the curves in figures 4 and 5.

The fixed carbon dioxide reached its maximum in the winter and its minimum in the spring. The smaller amount in the spring was due to the melting of the ice and the inflow of surface water. December 1928 was a mild month, the temperature being unusually high, with no snow until January. Rains and surface drainage account for the small amount of fixed carbon dioxide noticed on December 20 of that year. In the following January, however, it rose above the November figure, showing

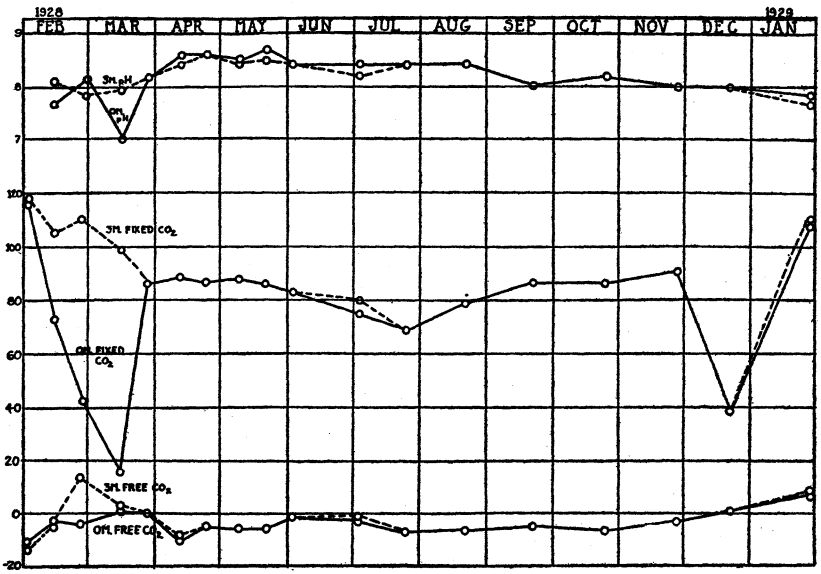

FIGURE 4. Carbon dioxide and hydrogen-ion curves 1928–1929. Carbon dioxide is given in parts per million; hydrogen-ion concentration in pH. 3M = three meters; OM = surface.

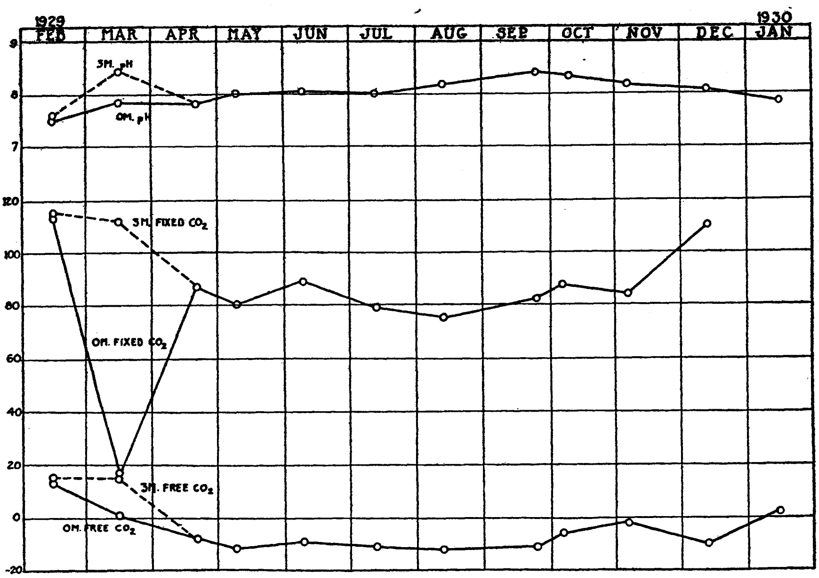

FIGURE 5. Carbon dioxide and hydrogen-ion curves 1929–1930. Carbon dioxide is given in parts per million; hydrogen-ion concentration in pH. 3M = three meters; OM = surface.

that the decrease was a temporary one. The bottom always showed a greater amount of fixed carbon dioxide than the surface.

Hydrogen-ion. The hydrogen-ion concentration as given in terms of pH shows correlation with the other physical and chemical factors only in a general way, due probably to the presence of a comparatively large amount of buffer salts. As the free carbon dioxide rose in the winter there was a slight decrease in the pH (see figures 4 and 5). The hydrogen-ion concentration of the surface water varied in general between pH 7.8 and pH 8.7. A reading of pH 7.0 was observed in March 1928, but this was due to the dilution of the water by melting ice. The higher pH figures are correlated with the activity of the phytoplankton.

Chlorides. Tests for chlorides were made for the first few months, but as they showed only an occasional trace they were discontinued.

Phosphorus. The work of Atkins (1923, 1925, 1926) and Atkins and Harris (1924) suggests a direct correlation between phosphorus and plankton growth. Atkins states that phosphorus is a limiting factor in the growth of plankton. Juday, Birge, Kemmerer and Robinson (1927), however, found no correlation between the soluble phosphorus and the phytoplankton, nor between the organic phosphorus and the centrifuge plankton. Wimmer (1929) working on limestone quarry pools in which there was an abundant plankton growth found little or no correlation between phosphorus and the amount of plankton growth.

A comparison of the organic matter in the centrifuge plankton and the curves for phosphorus (figures 6 and 7) shows little correlation between the centrifuge plankton and the organic phosphorus, and little between the soluble phosphorus and the phytoplankton (see also the spherical curves of the plankton counts in figures 10 and 11). The maxima for the plankton organic matter do not always correspond with those of the organic phosphorus. The soluble phosphorus falls to a small amount during the summer months as it is used up by the plankton and rises again in the fall with the decrease in the plankton. There was a marked rise in the soluble phosphorus correlated in time with the rise in the organic matter in the fall of 1929. It is pos-

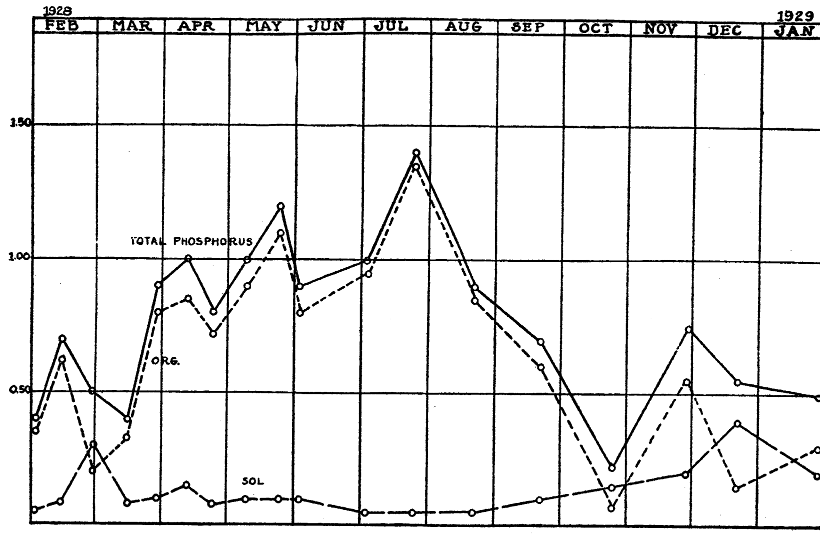

FIGURE 6. Phosphorus curves 1928–1929. Soluble, organic and total phosphorus are given in parts per million.

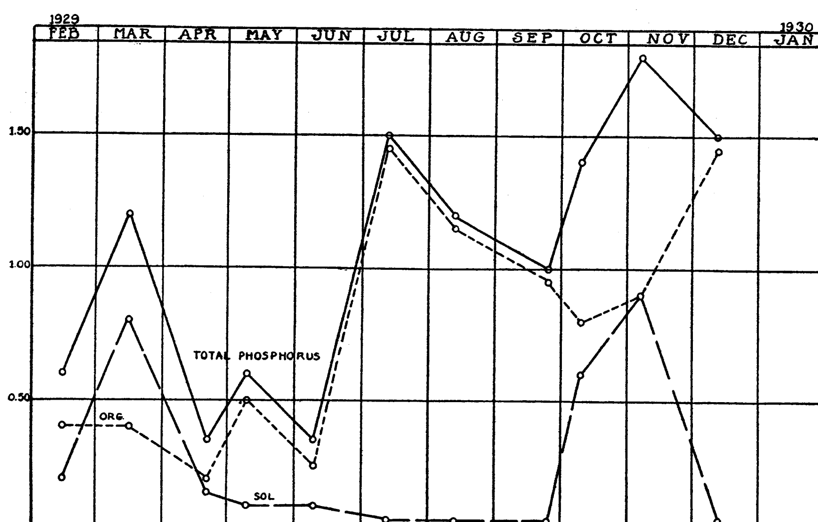

FIGURE 7. Phosphorus curves 1929–1930. Soluble, organic and total phosphorus are given in parts per million.

sible that the great decrease following this was due to the plankton using up all of the soluble phosphorus, but there was no corresponding rise in the organic phosphorus at the time of the increase in the organic matter. There are so many conflicting results that no case can be made for phosphorus as a limiting factor in plankton growth in Lake Wingra.

Usually the organic phosphorus made up the greater part of the total phosphorus, but on several occasions the curves show the amount of soluble phosphorus to be greater than that of the organic. On October 24, 1928 this occurred at a time when the organic matter in the centrifuge plankton was at a high point.

The organic phosphorus had its maxima in the summer of both years with secondary maxima in the spring and fall. Wright found the organic phosphorus to be high in fall and early spring and low in summer and winter. He also found little agreement between the organic phosphorus and the organic matter.

Silica. A direct correlation between the amount of silica dissolved in the upper waters and the diatom growth was reported by Birge and Juday (1911). In the summer the silica declined to a small amount in the upper water due to removal by the diatoms in building their shells. The amount of rain water draining into a lake was also shown to be an important factor by Pearsall (1923). In the spring and fall the silica is washed into the lakes by heavy rains and this accounts, he thinks, for the increase in diatom growth at these times.

In Lake Wingra the results for silica were similar in a general way to those reported by Birge and Juday, although the correlation was not a marked one. The maximum occurred in winter and the amount decreased in the spring of both years due to a large crop of diatoms consisting largely of synedra. The maximum amount of silica found was 15.0 parts per million in February and December 1928 while the minimum amount was observed on April 24, 1928, when but 0.3 part per million was present.

Nitrogen. Quantitative determinations of the nitrite nitrogen were made from February to May 1928. The amount rose from .003 part per million to .02 p.p.m., the greatest amount being observed on April 11 and May 9, 1928. The increase in spring is due to the increased amount of decomposition which goes on at the bottom as the water warms up and is mixed from bottom to top by the winds. In a general way, nitrate nitrogen (see figures 8 and 9) was found to vary inversely with organic nitrogen.

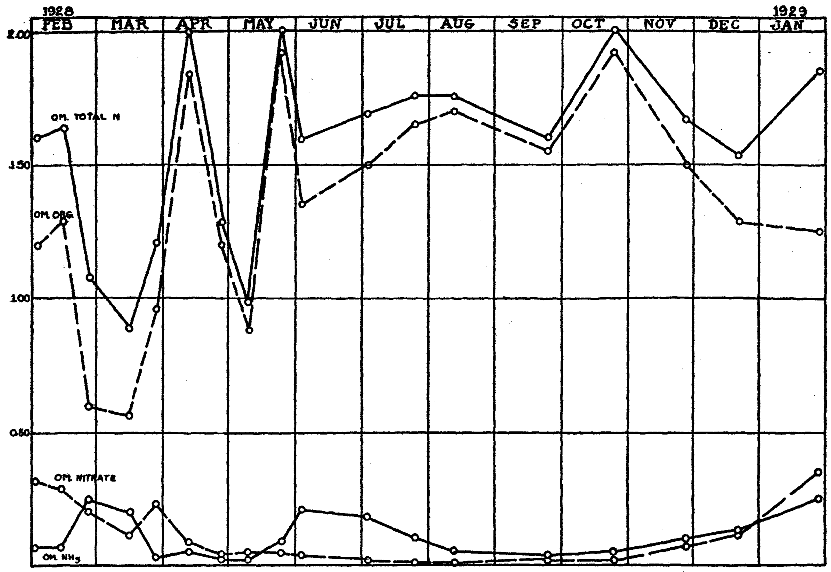

FIGURE 8. Nitrogen curves 1928–1929. Nitrate, free ammonia, organic and total nitrogen are given in parts per million. OM = surface (zero meters).

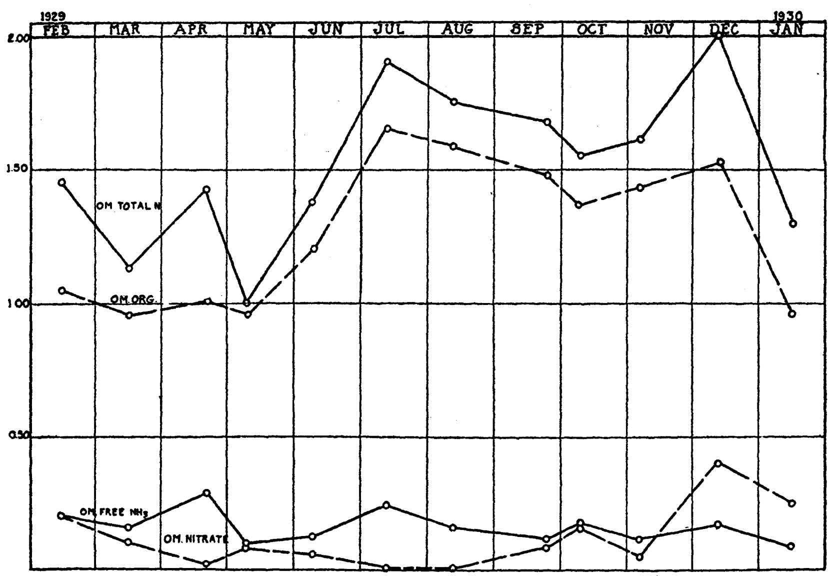

FIGURE 9. Nitrogen curves 1929–1930. Nitrate, free ammonia, organic and total nitrogen are given in parts per million. OM = surface (zero meters).

The plants use up the nitrates and this would give a large amount of organic nitrogen, mainly in the plants themselves. In the spring of 1928 the organic nitrogen fell to its lowest point (0.56 p.p.m.) while the nitrates, though declining, were rather high. Again in the fall of the same year the organic nitrogen decreased, while the nitrates were increasing. The maximum amount of organic nitrogen was found in the spring and summer when the plant life was abundant and also when there was little nitrate nitrogen present.

The free ammonia nitrogen (figures 8 and 9) followed in a general way the nitrate nitrogen, being higher in winter than in summer. The ammonia nitrogen was higher at the first part of the summer and then gradually declined throughout the remainder of the summer. It reached a low point by the end of the summer and then steadily rose during the winter. It decreased in March and April and was low until the rise at the early part of the summer. The high ammonia figures in winter were probably due to the decrease in the activity of the denitrifying bacteria at a time when the water was cold. Nitrates were broken down through nitrites to ammonia, but probably the final step to nitrogen was carried out only to a limited extent. There is little plant life during the winter to use up the nitrates so they are able to accumulate at this time. As the temperature of the water rises in spring the plants become increasingly active and although decomposition is increased the nitrates are used up at such a rate that the water is almost depleted by early summer. The plant requirements keep the nitrates low during the summer and it is only in the fall that the amount of nitrate nitrogen rises as the plants decrease in numbers. Nitrites and nitrates are also formed from ammonia during the summer and this increases the available nitrate for the plants. The rise in ammonia in the early part of the summer (June) occurs at a time when the centrifuge plankton organic matter is low, just previous to the rise in summer and following the spring maximum. The decomposition of the plankton organisms accounts for this rise in ammonia in early summer.

Domogalla and Fred (1926) found high ammonia in spring and winter while Wright did not find the rise in spring following the maximum for plankton. Domogalla and Fred found that the nitrates were high in winter and spring and low in summer, which agrees very well with Wright's findings. The springs which feed Lake Wingra were found to be high in nitrates by Domogalla. In a determination made November 23, 1925 Wright found that the Nakoma spring had 3.5 p.p.m. of nitrate nitrogen, while the Wingra spring had 1.9 p.p.m. This accounts for the fact that the waters of Wingra contain a larger amount of nitrates than the other Madison lakes.

Organic matter from centrifuged samples. In 1926 the junior author found the maximum amount of organic matter from centrifuged samples in Lake Wingra in the late spring and in the fall. Wright obtained his maximum in the summer. In both 1928 and 1929 there was a maximum in the spring at the same time as the counts for plankton organisms indicated, and a lower peak in the fall at the time of the fall maximum in plankton organisms.

Dissolved organic nitrogen and carbon. Analyses made on the residues from evaporated water gave the dissolved organic carbon and nitrogen as shown in the accompanying table. The crude protein figure is obtained by multiplying the nitrogenous organic carbon by 6.25. The non-nitrogenous organic carbon is reported as carbohydrate, as in Birge and Juday (1926).

TABLE I—*The results of analyses on residues (Res.) for nitrogen (N), carbon (C), crude protein (C. P.), non-nitrogenous carbon (Nonn.), total organic carbon (Total), and the carbon nitrogen ratio (C/N). The results are expressed in milligrams per liter of water.*

Date	*Res.*	*N*	*C*	*C/N*	*C. P.*	*Nonn.*	*Total*
Feb. 16, 1929	307.0	1.160	15.95	1:13.8	7.25	26.91	34.16
Mar. 15, 1929	303.8	0.688	7.25	1:10.5	4.30	11.04	15.34
May 10, 1929	232.2	0.504	8.14	1:16.1	3.15	14.38	17.53
Jun. 10, 1929	233.2	0.601	7.51	1:12.5	3.76	12.27	14.03
Nov. 6, 1929	248.9	0.637	9.01	1:14.1	3.99	15.33	19.32
Dec. 13, 1929	283.2	1.180	9.17	1:12.3	4.66	14.91	19.57
Jan. 15, 1930	290.7	0.803	8.50	1:10.6	5.02	12.94	18.00
Mean		0.796	9.30	1:12.8	4.59	15.39	19.71

THE PLANKTON

Domogalla and Fred (1926) give figures for the amount of organic matter and number of plankton organisms in Lake Wingra from March to December 1925. Two maxima were found, one in June and the other in October. The maximum for the organic matter, however, occurred in August.

In deeper lakes spring and fall maxima are usually explained

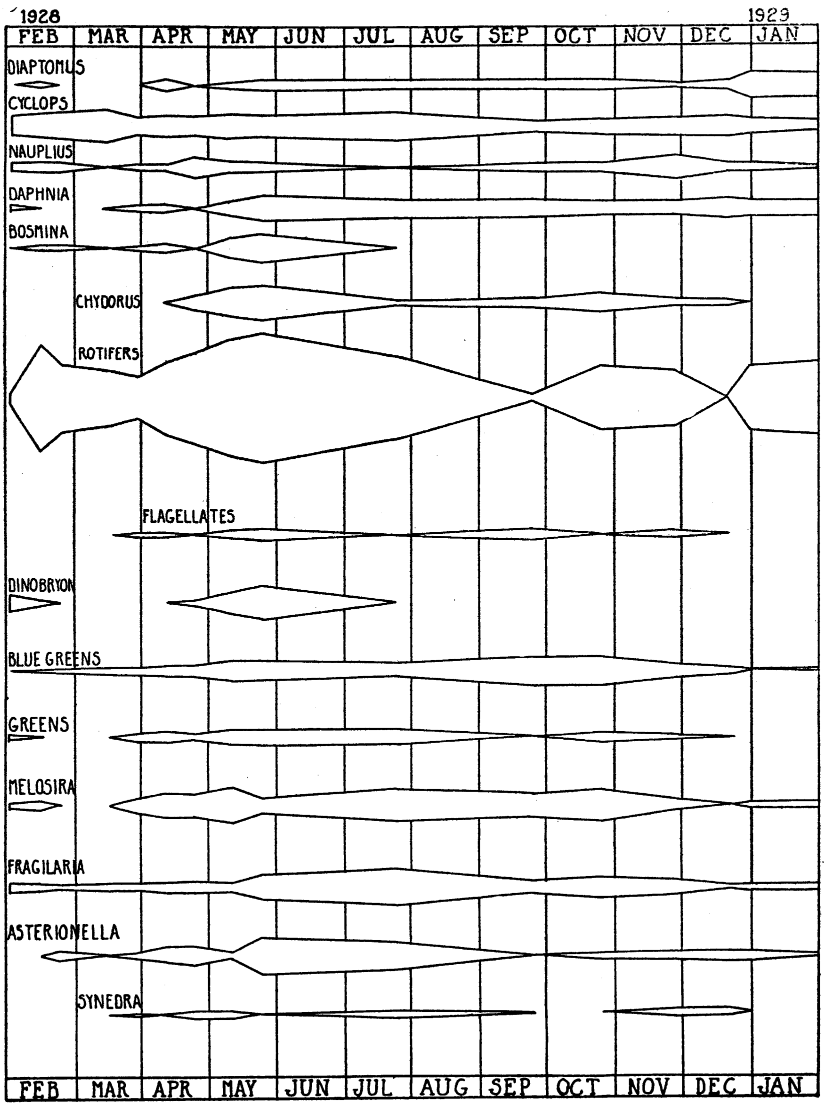

FIGURE 10. Spherical curves of net plankton counts 1928–1929. Crustacea and rotifers are shown as organisms per cubic meter; remainder as organisms per liter.

by assuming that decomposition products accumulate in the lower water while the water is stratified in summer and winter, carrying with them stored up food for other organisms so that the upper waters are depleted. At the spring and fall overturns these food substances are made available and we find a correspondingly marked increase in the plankton. Lake Wingra is such a shallow lake and the stratification is so slight that spring and fall maxima cannot be explained on this basis.

The diatoms are characteristic forms and at times are found in large numbers. Wright found Synedra in April 1927 to the number of eight million per liter, while in April 1928 it occurred in numbers as high as sixty million per liter. This accords very well with Pearsall's findings (1921, 1922), namely that lakes with an abundant supply of silica are diatom lakes predominantly. The diatoms are found to be most abundant in the spring and again, but to a lesser extent and for a shorter period, in the fall. During the winter months they declined. Synedra was the most abundant genus, being taken at most times of the year, and at its maximum in the spring, far exceeding all the other forms combined. Melosira was also taken in nearly every haul during the two years and at times reached a high figure in the counts.

The blue greens, while present in considerable numbers, were never as abundant as in the other Madison lakes. They were never the cause of noxious odors in Wingra. Microcystis and Coelosphaerium were the most abundant forms and had their maxima in the early fall or late summer, although they were quite abundant throughout the summer. Aphanizomenon also was prominent among the blue greens and like Microcystis occurred in large numbers in the late summer and early fall.

The green algae were abundant at most times except during the winter. Pediastrum was plentiful throughout the summer with maxima in the spring and fall. Oocystis was most abundant in May with another maximum in early fall. Oocystis was the most abundant of all the green algae, although Scenedesmus was more consistently present, and at times (April and May) was nearly as abundant as Oocystis. The other forms appeared intermittently in the counts and showed maxima in the spring and fall.

Wright found that Cyclops was the most abundant crustacean; Diaptomus, Daphnia and Chydorus were present in smaller numbers. This was also true in 1928 and 1929. Cyclops was taken in every sample throughout the two years. The crustacea

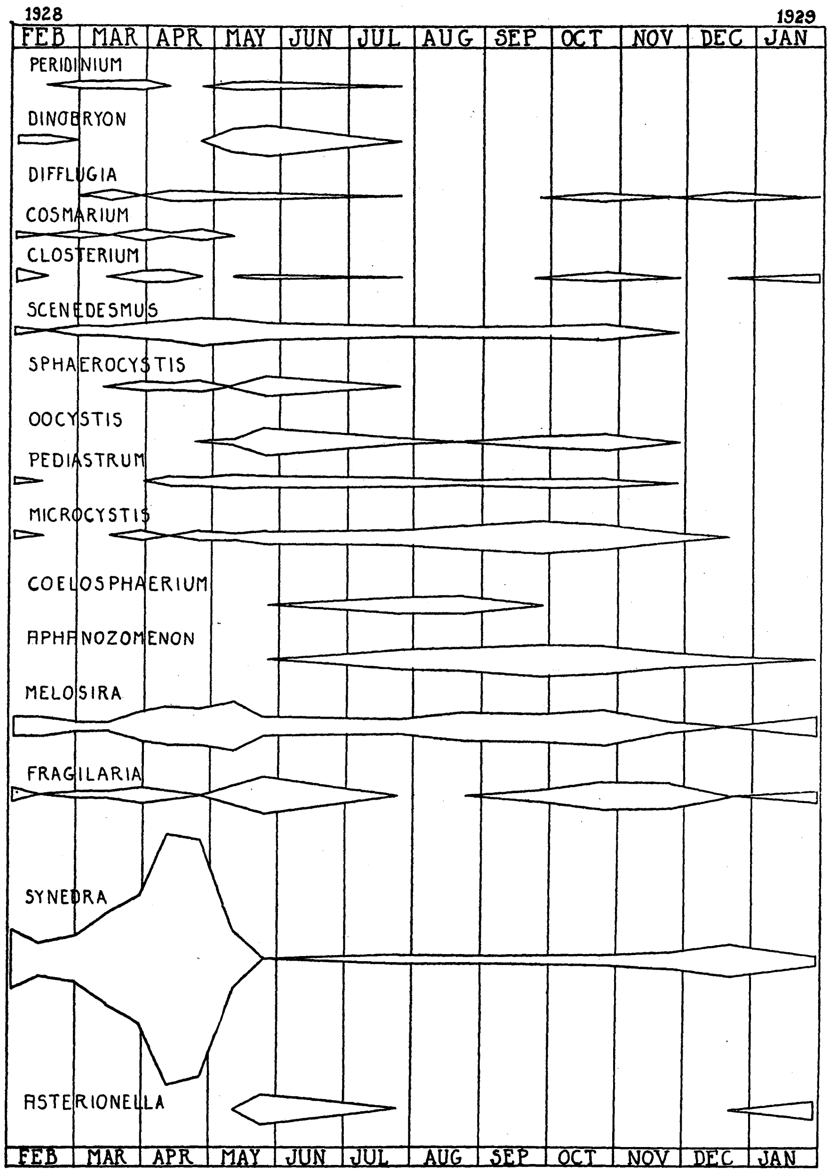

FIGURE 11. Spherical curves of centrifuge plankton counts 1928–1929. Plankton organisms are shown as organisms per liter.

reached a maximum in fall and again in the spring. The nauplii usually had their maxima at these times although this did not seem to be definite. Daphnia was present at most times of the year. Bosmina and Chydorus were at a maximum in early summer.

The rotifers had their maximum in early spring of 1928 but were not found in the summer of 1929. They then reappeared in large numbers in the fall of 1929. The most prominent forms were Anuraea, Polyarthra, Asplanchna, Triarthra and Notholca.

Of the protozoans, Dinobryon had its maximum in the spring of 1929 and was then never seen again in the samples. Peridinium and Difflugia were also seen at times (figures 10 and 11).

SUMMARY

Lake Wingra is a small, shallow body of water at the outskirts of Madison, Wisconsin. It shows very little stratification, even in winter under the ice. The difference in temperature between surface and bottom rarely exceeds five degrees. A maximum of 26°C was observed at the surface in summer. A fairly strong wind will mix the water from surface to bottom when the lake is open. The transparency varies between 0.5 m. and 2.5 m. as shown by the Secchi disc. The conductivity averages about 330 units (reciprocal of megohm resistance) and varies between 290 and 390. The color is slight, about 18 on the platinum-cobalt scale. Oxygen is present at all depths and at all times of the year in sufficient quantities to support animal life. Free carbon dioxide is found at the surface only in winter; at all other times there is a deficiency. The water contains a large amount of fixed carbon dioxide, which may attain 110 p.p.m. The pH varies between 7.8 and 8.7. Chlorides were found in minute traces only. Organic phosphorus is high in summer, low in winter. Soluble phosphorus is low in summer and high in winter. The dissolved silica is abundant and shows some correlation with the numbers of diatoms. The nitrates are high at all times, and are highest in winter. Free ammonia is highest in winter with a secondary rise in spring. Ammonia and nitrates are low in summer. Organic nitrogen is low in winter and high in spring and summer; it parallels the plankton curve fairly closely. The average amount of organic carbon is 9.0 p.p.m. The organic matter in the centrifuge plankton follows roughly the number of plankton organisms. The diatoms are most abundant of all the plankton organisms, being found in

large numbers in the spring and in somewhat smaller numbers in the fall. In summer the blue greens are quite abundant. Of the crustaceans, Cyclops is the most abundant.

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A SECOND REPORT ON THE PHOSPHORUS CONTENT OF WISCONSIN LAKE WATERS

C. JUDAY AND E. A. BIRGE

Notes from the Limnological Laboratory of the Wisconsin Geological and Natural History Survey. No. XLII.*

INTRODUCTION

A general chemical survey of the lake waters of the Highland Lake District of northeastern Wisconsin was begun in 1925 and has been continued up to the end of the summer season of 1930. During this period samples of water and of residues have been secured from 529 lakes and lakelets in this district. Various chemical determinations have been made on these water samples and residues, such as quantitative studies of the dissolved gases, organic carbon, nitrogen, iron, silica, calcium, phosphorus, chlorine and sulphate. This chemical investigation has now progressed far enough to warrant the preparation of reports on some phases of the results that have been secured, and the phosphorus data have been selected for the present report.

The phosphorus results obtained on 88 of these lakes in 1925—1926 were presented in a previous paper (Juday et al., 1928) and this second report includes all of the observations that have been made up to the end of the 1930 season. Methods of making the chemical determinations were given in the 1928 report and they have been discussed also by Robinson and Kemmerer (1930) so that they need not be repeated here.

The same terminology is employed in this report as in the previous one. The phosphorus which is found in the untreated sample of water by the ceruleomolybdic method is called the "soluble" or phosphate phosphorus. The result obtained after treating the sample of water with oxidizing agents represents the total phosphorus. Deducting the "soluble" or phosphate phosphorus from the total phosphorus gives the so called "organic" phosphorus. It was pointed out in the 1928 report that

* This investigation was made in cooperation with the U. S. Bureau of Fisheries and the results are published with the permission of the Commissioner of Fisheries.

all of the phosphorus which has been classed as "organic" may not be in organic compounds, but that part of it may be present in an inorganic form which does not appear in the "soluble" or phosphate determination. These lake waters always carry a certain amount of silt and this silt may contain some phosphorus which is not ordinarily available in the soluble phosphorus procedure, but which becomes available after the more drastic treatment in the total phosphorus determination. It does not seem probable, however, that any appreciable amount of inorganic phosphorus is present in such a form that it will not be included in the phosphate determination. In the tables the phosphorus results are indicated in milligrams of the element per liter of water in order to keep them uniform with the results of the other chemical determinations.

Sources of Phosphorus

The soil and subsoil of the lake district as well as the underlying strata through which the underground water passes are the chief sources of this lacustrine phosphorus. According to a reconnoisance survey by Whitson et al. (1916) several types of soil are found within the boundaries of this lake district and the different types show considerable differences in the amount of phosphorus which they contain. The quantity of this element in the various soils ranges from 953 to 1570 kilograms per hectare in the upper 20 centimeters (850 to 1400 pounds per acre in the upper 8 inches); in 34 analyses of soils from this district, phosphorus constituted an average of 0.0486 per cent of the dry weight of the samples. The second 20 centimeters (8 inches) contains from 673 to 785 kilograms of phosphorus per hectare (600 to 700 pounds per acre). No results for deeper strata are given in their soil report. The soil phosphorus undoubtedly makes a very important contribution of this element to the water which drains into these lakes.

The ground water also serves as a source of supply. In order to ascertain the phosphorus content of the underground water of the region, samples were obtained from 19 wells and one spring during the summer of 1930. The results of the determinations are shown in table I, where the quantity of phosphorus is indicated in milligrams per liter of water. The wells are located on the shores of 13 different lakes and they are widely distributed in the district, so that they probably represent the general variation within the region covered by them; they extend over a distance of about 68 km. in an east-west direction and about 48 km. in a north-south direction.

The total phosphorus ranged from a minimum of 0.002 mg. per liter in Anderson's well at Little Bass Lake to a maximum of 0.197 mg. in the well at Big Arbor Vitae Resort on Arbor Vitae Lake; this represents approximately a hundred-fold difference in amount, and these two wells are only about 4 km. apart. The mean quantity of phosphorus in the 19 samples is 0.029 mg. per liter of water and this is somewhat larger than the mean quantity of total phosphorus in the surface water of 479 lakes, namely 0.023 mg. per liter. Omitting the highest two, namely the Big Arbor Vitae Resort well and the Bent well at Lake Mamie, the mean quantity for the other 17 is only 0.016 mg. per liter, which is smaller than the average content of the surface waters of the lakes. The spring water at Little Papoose Lake yielded the same amount as the latter mean, namely 0.016 mg. per liter. Phosphorus constituted from 0.001 per cent to 0.203 per cent of the dry weight of the residues obtained from the well waters. The residue of the spring water yielded 0.022 per cent of phosphorus.

Soluble or Phosphate Phosphorus

Surface waters. Soluble phosphorus determinations have been made on the surface waters of 494 lakes during the time of these studies. Most of these observations have been confined to the summer season, that is, from June 25 to August 31 each year during the progress of this work. In this period 936 determinations have been made on surface waters and 305 of them represent only a single determination on a lake; two determinations have been made on each of 75 lakes and three or more on 114 lakes. The largest number (17) has been made on Trout Lake.

The quantity of soluble phosphorus in the surface waters of the various lakes ranged from none in nine lakes to a maximum of 0.015 mg. per liter in one. Figure 1 shows a grouping of the lakes on the basis of the amount of soluble phosphorus in the surface water. Where more than one determination has been made on a lake, the mean of the various readings has been used in constructing the diagram. Lake Mary, which had the maximum amount, has been omitted from the diagram in order to shorten the figure somewhat.

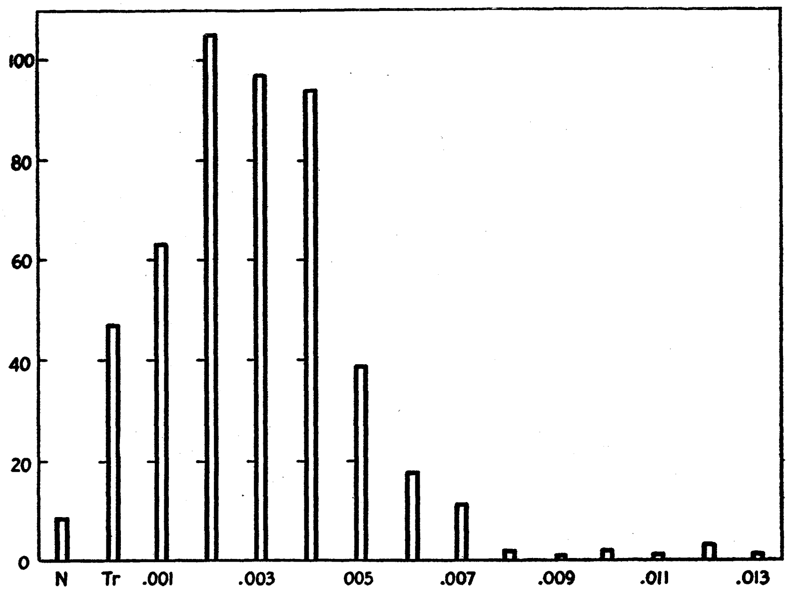

FIG. 1. This diagram shows the grouping of the lakes on the basis of the amount of soluble phosphorus in the surface water; 494 lakes are included in the figure. The quantity of soluble phosphorus ranges from none to 0.013 mg. per liter of water. The vertical spaces represent the number of lakes in each group. N = none, Tr. = trace.

In 47 lakes, or 9.5 per cent of the total number, the quantity of soluble phosphorus was too small to measure, so they were listed as having only a trace. Adding these to the nine which had no soluble phosphorus gives a total of 56 lakes, or a little more than 11 per cent of the total number, with only a trace or no soluble phosphorus at all at the time the samples were taken.

The 0.002 mg. column has the largest number of lakes, namely 105, but the 0.003 and 0.004 mg. groups are nearly as large since they contain 97 and 94 lakes respectively. These three groups include 60 per cent of the 494 lakes. In comparison with these the 0.001 mg. group includes 63 lakes and the 0.005 mg. group 39 lakes. Beyond the latter the 0.006 group contains only 18 lakes and the 0.007 mg. group 11 lakes. Above these groups the columns represent only one to three lakes each. The 0.001 mg. to 0.005 mg. groups inclusive, represent 398 lakes, or 80 per cent of the total number. Expressed in another way the surface waters of these 398 lakes contained from 2.3 mg. to 11.5 mg. of P_2O_5 per cubic meter. The mean quantity of soluble phosphorus in the surface waters of the 494 lakes was approximately 0.003 mg. per liter, or about 6.9 mg. of P_2O_5 per cubic meter.

Seasonal variations. The results obtained during the spring and summer of 1926, as reported in our previous paper (1928), did not show any consistent decrease in the quantity of soluble or phosphate phosphorus in the surface waters as the season advanced. In order to secure further evidence on this point, a similar study of the surface waters of 25 of these northeastern lakes was made during the spring and summer of 1927. As in the former year, the observations in the spring were made as soon as possible after the ice disappeared, that is, from May 2 to May 8, inclusive. The summer readings were taken between June 25 and August 26.

The results of the 1927 series are shown in table II. In 15 lakes a smaller amount of soluble phosphorus was found in July and August than in May, the decrease amounting to 0.001 to 0.012 mg. per liter; in 7 lakes the amounts were the same, while in 5 cases a larger amount was obtained in July and August than in May, the increase amounting to 0.001 to 0.002 mg. per liter. Similar results were obtained in the spring and summer observations of 1925 and 1926. During the three years (1925—1927) spring and summer determinations were made on 32 different lakes; some of these lakes were visited in only one of these years, some during two years and others during all three years, so that 54 pairs of spring and summer observations were secured in the three years. Of this number 26 pairs showed a smaller amount of soluble phosphorus in summer than in spring, 12 pairs were the same and 16 pairs yielded a larger amount in summer than in spring. Thus in a little more than half of the cases the amount of soluble phosphorus was the same or larger in the summer than it was in May. This was true despite the fact that some of these lakes supported an abundant growth of phytoplankton. In Blue Lake, for example, the surface water contained 1,236,000 cells and colonies of phytoplankton organisms per liter on May 2, 1927 and 1,849,000 on the following July 8, yet the soluble phosphorus was 0.005 mg. per liter on the former date and 0.007 on the latter. In Mann Lake also there were 10,969,000 phytoplankton organisms per liter in the surface water on May 5, 1927 and 12,357,000 on the following August 26, with the same amount of soluble phosphorus on both dates, namely 0.005 mg. per liter.

In the shallower lakes, more especially in those where the water is kept in circulation throughout its entire depth during the summer, the supply of phosphorus is most probably maintained or increased through regeneration by the decomposition of organic matter and also by the inflow of tributary waters containing this element. In the lakes that are deep enough to be thermally stratified in summer, a large part of the organic matter decomposes in the hypolimnion and the soluble phosphorus derived from it remains in this stratum until the autumnal overturn and circulation of the water takes place. Some of the stratified lakes, however, such as Big Carr, Clear, Crystal, Silver and Trout with maximum depths ranging from 19 to 35 meters, have maintained or increased their supplies of soluble phosphorus in the surface water during the summer. Three of these lakes, Big Carr, Clear and Crystal, have neither an inlet nor an outlet so that they are dependent chiefly upon ground water for their mineral constituents. Also Silver Lake does not have an inlet and there is an outflow only in periods of high water. In view of these facts, it is not clear at present just how such lakes maintain their stocks of soluble phosphorus in the upper water throughout the growing season.

The results of 1927 are also like those of 1925—1926 in that they do not show any correlation between the quantity of soluble phosphorus and the amount of fixed carbon dioxide in the water. In the May determinations of 1927, for example, the surface waters of Arbor Vitae and Crystal lakes yielded the same amounts of soluble phosphorus (0.007 mg. per liter), while the former had eleven times as much fixed carbon dioxide as the latter. (See table II). The same was true of Arbor Vitae and Weber lakes where there was a twenty-two-fold difference in carbon dioxide content. Madeline and Island lakes had the same amounts of soluble phosphorus, but the former had approximately twenty times as much fixed carbon dioxide as the latter.

The results show several other illustrations of this lack of correlation between soluble or phosphate phosphorus and the carbonates.

Vertical distribution. The vertical distribution of the soluble phosphorus has been studied on 66 different lakes; these observations comprised 178 series of three or more samples which covered the entire depth of the various lakes. The results for some of the series taken in 1927 are shown in table II and in figures 2 to 8. While a considerable number of vertical series were taken in 1928 and 1929, they have not been included in the table because those given for 1927 illustrate the two general types of vertical distribution that have been found. The first

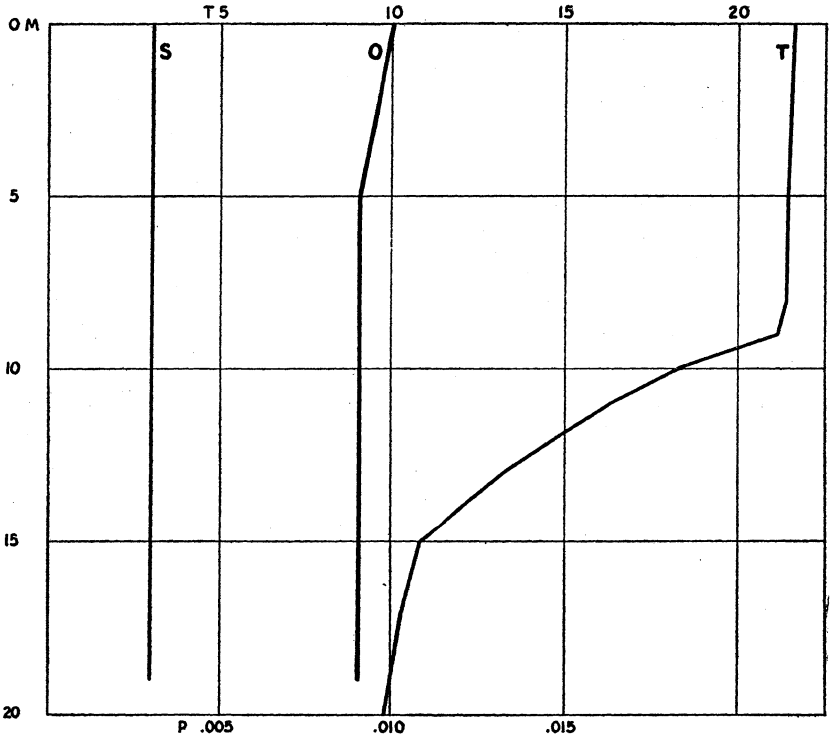

FIG. 2. Vertical distribution of phosphorus and temperature in Crystal Lake on August 21, 1928. Depths are indicated in meters; the scale at the top of the diagram represents the temperature in degrees centigrade and the bottom scale represents the quantity of phosphorus in milligrams per liter of water. S = soluble phosphorus, O = organic phosphorus, and T = temperature.

type includes those lakes in which there is a uniform distribution of soluble phosphorus from surface to bottom throughout the summer period of stratification and the second includes those in which there is a more or less marked rise in the soluble phosphorus at the bottom, especially toward the end of the summer season.

Crystal Lake is a good example of the uniform type of distribution. Figure 2 shows the results obtained on this lake on August 21, 1928. Crystal Lake has neither an inlet nor an outlet and its water contains very little fixed carbon dioxide as indicated in table II. It supports a relatively small crop of phytoplankton which means a correspondingly small demand for phosphorus by this crop. Zooplankton forms are present in sufficient abundance to control the growth of the phytoplankton so that very little of this algal material settles into the lower water and decomposes there, consequently there is not the usual transference of phosphorus from the upper to the lower strata of water by these organisms. Figure 2 shows that the soluble phosphorus was uniformly distributed from surface to bottom even as late in the season as August 21. Similar results were obtained in a series on Lake Laura on August 9, 1926, on Little Trout on August 24, 1927 (fig. 3) and on Stormy Lake on August 16, 1928. A uniform distribution has also been noted in some of the other lakes in late June or early July, but samples obtained during late July or in August showed a larger amount of soluble phosphorus in the lower water than at the surface; these lakes, therefore, belong to the second type. In order to determine to which of the two groups a lake belongs, it is necessary to have a set of observations made during the latter part of the summer period of stratification, that is, in late July or in August.

The great majority of the lakes that are deep enough to become stratified in summer belong to the second type, that is, those in which there is a more or less marked rise in the amount of soluble phosphorus in the lower water. These lakes show very wide differences in the range of this increase in the lower water. In some of them the lower water may contain only 0.001 to 0.002 mg. per liter more than the surface in late summer, while in others the differences are very much greater. In Blue Lake on August 6, 1929 the range was from 0.002 mg. at the surface to 0.003 mg. at the bottom (12 m.) and on August 13, 1926 the quantity of soluble phosphorus was 0.004 mg. at the surface and 0.006 at the bottom. In Fence Lake the amount increased from 0.001 mg. per liter at the surface to 0.003 mg. at the bottom (28 m.) on August 23, 1929. The varying degrees of increase from surface to bottom are shown in figures 4 to 8.

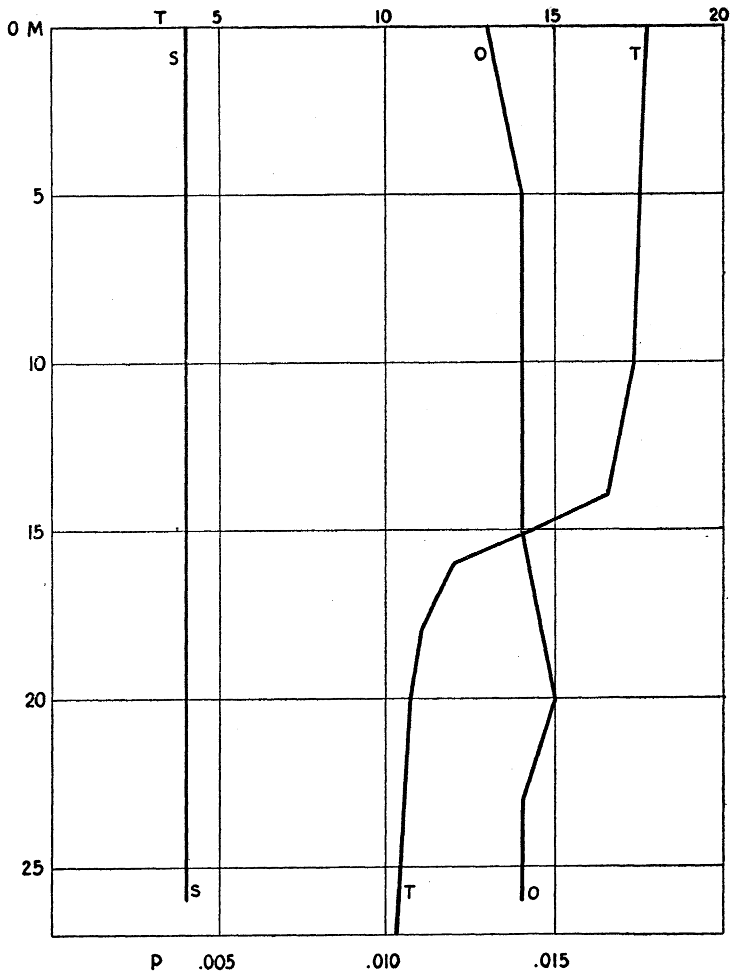

FIG. 3. Vertical distribution of phosphorus and temperature in Little Trout Lake on August 24, 1927. See fig. 2 for further explanations.

In Trout Lake (fig. 5) the quantity of soluble phosphorus rose from 0.003 mg. per liter at the surface to 0.008 mg. at the bottom (31 m.) and in Big Carr from 0.005 mg. at the surface to 0.009 mg. at 21 m. Larger differences were found in Clear Lake (fig. 4), Adelaide (fig. 6), and Big (fig. 8). Still larger differences were noted in some other lakes, such as Upper Kabasheen (table II), where the range was from 0.007 mg. at the surface to 0.190 mg. at 16 m., Black Oak with 0.004 mg. at the surface and 0.095 at 24 m., Bragonier with 0.001 mg. at the surface and 0.150 mg. at 8 m., and Nebish with 0.003 mg. at the surface and 0.240 mg. at 14 m. The maximum difference be-

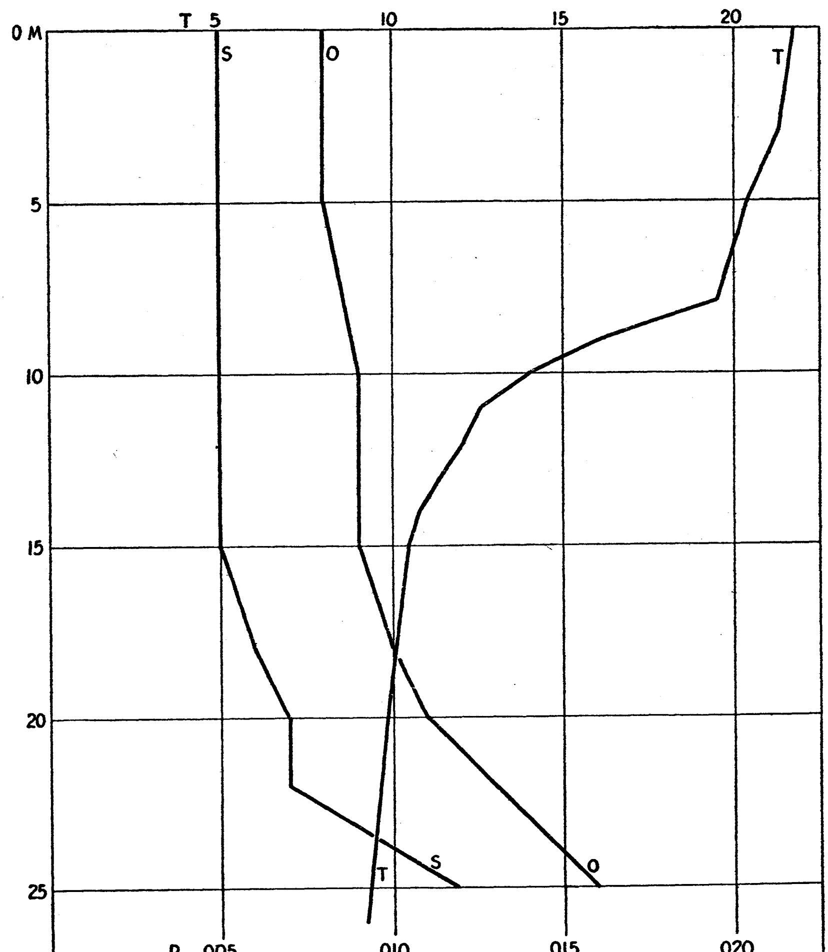

FIG. 4. Vertical distribution of phosphorus and temperature in Clear Lake, July 27, 1927. See fig. 2 for further explanations.

tween surface and bottom was found in Lake Mary; the range in this lake on July 12, 1926 was from none at the surface to 0.750 mg. per liter at the bottom (20 m.) and on July 11, 1928 from none at the surface to 0.500 mg. at 20 m. The results obtained on Lake Mary in 1927 are given in table II; the observations made on this lake on July 29, 1927 are also shown in figure 7. It should be noted that the phosphorus scale of this diagram is twenty times as large as that for the other lakes. The results obtained on Lake Mary on May 7 indicate that the large amount of soluble phosphorus found in the lower water on July 29, 1927 was due in part, at least, to the winter accumulation as well as to that of the summer. Apparently there was not a complete overturning and circulation of the water in the spring of 1927 or there would have been a more uniform distribution of the soluble phosphorus at the time the samples were obtained in May. Lake Mary is small in size (1.12 ha.), well protected from the wind by the surrounding forest and has a maximum depth of 22.5 m., so that conditions are very favorable for an incomplete overturning of the water in the spring.

ORGANIC PHOSPHORUS

Surface waters. The grouping of the lakes on the basis of the quantity of organic phosphorus in the surface water is shown in figure 9. The vertical scale shows the number of lakes in the different groups and the horizontal scale represents the amount of organic phosphorus per liter of water. Determinations were made on the surface waters of 479 lakes and 454 of them are included in the diagram; four fall below the minimum of 0.008 mg. per liter in the diagram and 21 are above the maximum of 0.039 mg. The latter range from 0.042 mg. to a maximum of 0.103 mg. of organic phosphorus per liter of water; they are spread over such a wide range that they could not be included in the diagram conveniently.

The majority of the lakes shown in the diagram are grouped within rather narrow limits; 313 lakes, or more than 65 per cent of the total number, come within the limits of 0.009 mg. and 0.020 mg. inclusive, while extending the upper limit to 0.022 mg. would bring in 26 additional lakes, thus making a total of 339 lakes in these groups, or approximately 71 per cent of the total number. About 62 per cent, or 297 lakes, fall within the two-fold range of 0.010 to 0.020 inclusive. The mean quantity of organic phosphorus in the surface waters of the 479 lakes is 0.0203 mg. per liter; this is almost seven times as much as the mean quantity of soluble phosphorus in these lakes, namely 0.003 mg. per liter. Excluding the lakes which did not have any soluble phosphorus or only a trace in the surface water, the ratio of organic to soluble phosphorus ranges from approximately 1 to 1 up to 1 to 89. In one sample of water from Bould-

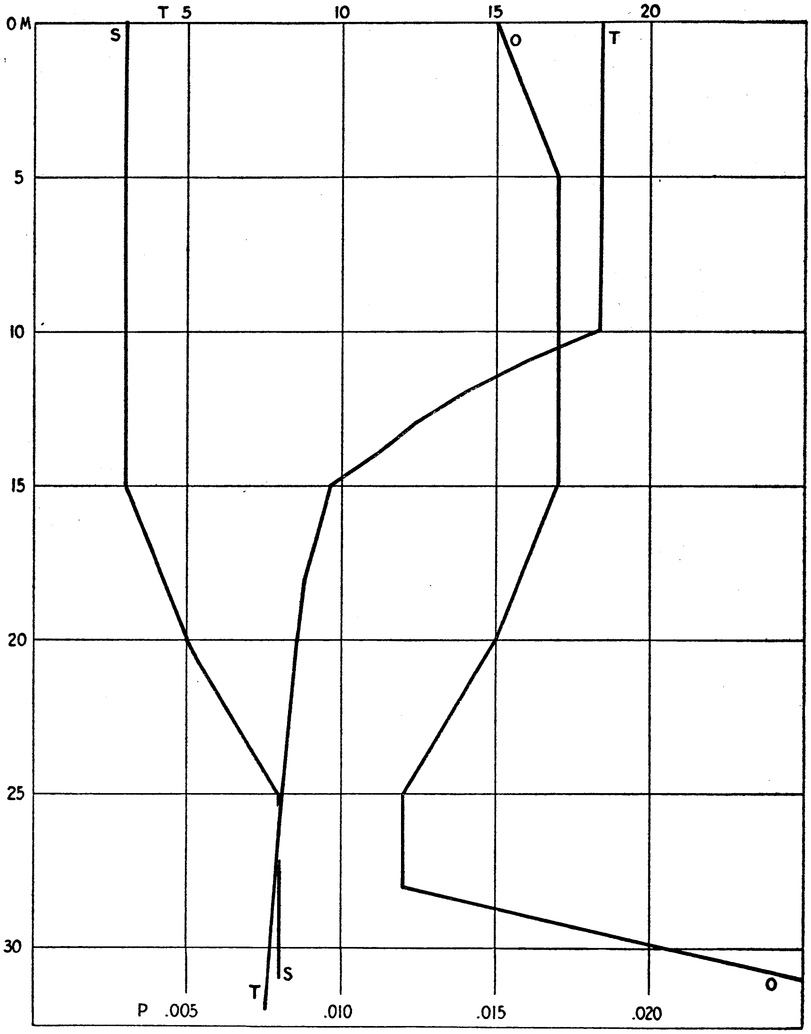

FIG. 5. Vertical distribution of phosphorus and temperature in Trout Lake, August 20, 1927. See fig. 2 for further explanations.

er Lake the soluble phosphorus amounted to 0.012 mg. per liter and the organic phosphorus to 0.013, or substantially a one to one ratio. A sample of surface water from Katherine Lake near Phelps contained 0.001 mg. of soluble phosphorus and 0.089 mg. of organic phosphorus per liter.

A comparison of the total organic matter and of the organic phosphorus shows a wide range of variation. The ratio of the former to the latter varies from 3046 to 253, a twelve-fold difference; the former was noted in Cranberry Lake where the organic matter was 27.42 mg. and the organic phosphorus 0.009 mg. per liter, and the latter in Eagle Lake of the Eagle River chain where the organic matter amounted to 26.14 mg. and the organic phosphorus to 0.103 mg. per liter. This wide range indicates that the organic matter found in the waters of the various lakes contains very different percentages of phosphorus.

These variations are shown graphically in figure 10 where the organic carbon is platted against the organic phosphorus. The organic carbon is used in this diagram instead of the organic matter because it represents a definite chemical determination, while the total organic matter is a computation based on the organic nitrogen and organic carbon determinations. Speaking roughly the organic matter is approximately twice as much as the organic carbon. Each dot in the diagram represents the results obtained on a single lake. It should be noted that the lakes represented in the various carbon lines also cover a wide range in the quantity of organic phosphorus. As illustrations of these wide variations, the following cases may be cited: in the 0.013 mg. organic phosphorus column the organic carbon varies from 2.0 mg. to 16.0 mg. per liter, while in the 7.0 mg. organic carbon line the organic phosphorus ranges from 0.009 mg. to 0.034 mg. per liter.

In spite of these large variations, however, there is an irregular but definite correlation between the increase in the organic carbon and the amount of organic phosphorus through the middle portion of the phosphorus range shown in figure 10. This correlation is shown more clearly in figure 11 where the mean quantity of organic carbon in the various columns is platted against the organic phosphorus. The solid line in this figure represents the actual means of the different organic phosphorus columns, while the broken line represents the running mean of

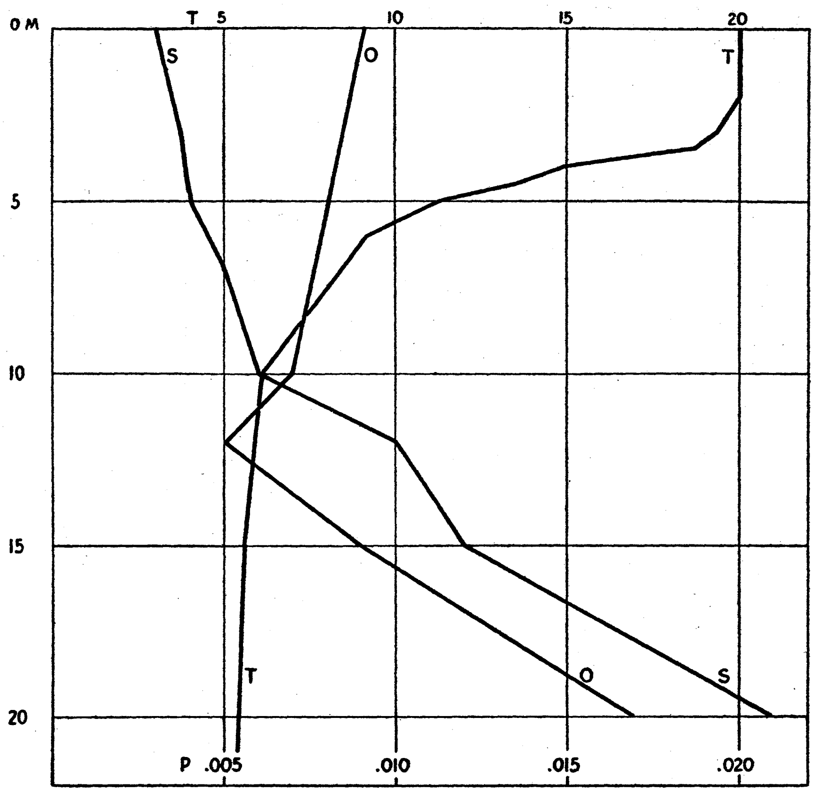

FIG. 6. Vertical distribution of phosphorus and temperature in Adelaide Lake, August 5, 1927. See fig. 2 for further explanations.

three columns. The most definite correlation begins at the point where the organic carbon amounts to 3.9 mg. and the organic phosphorus to 0.012 mg. per liter and continues until the organic carbon reaches 12.0 mg. and the organic phosphorus 0.025 mg. per liter.

In the phosphorus columns between 0.008 mg. and 0.012 mg. there is a decrease of organic carbon with an increase of organic phosphorus; above 0.025 mg. the curve is very irregular, but a general rise is indicated. The curve constructed by using a running mean of three columns is much smoother than that based on the means of the individual columns; but this curve also shows an irregularity above 0.028 mg. of organic phosphorus. The irregularities at the two ends of these curves are due in part at least to the small number of lakes represented by these segments of the curves. The significance of these variations and irregularities are not evident at the present time and further investigations will be necessary to determine their meaning.

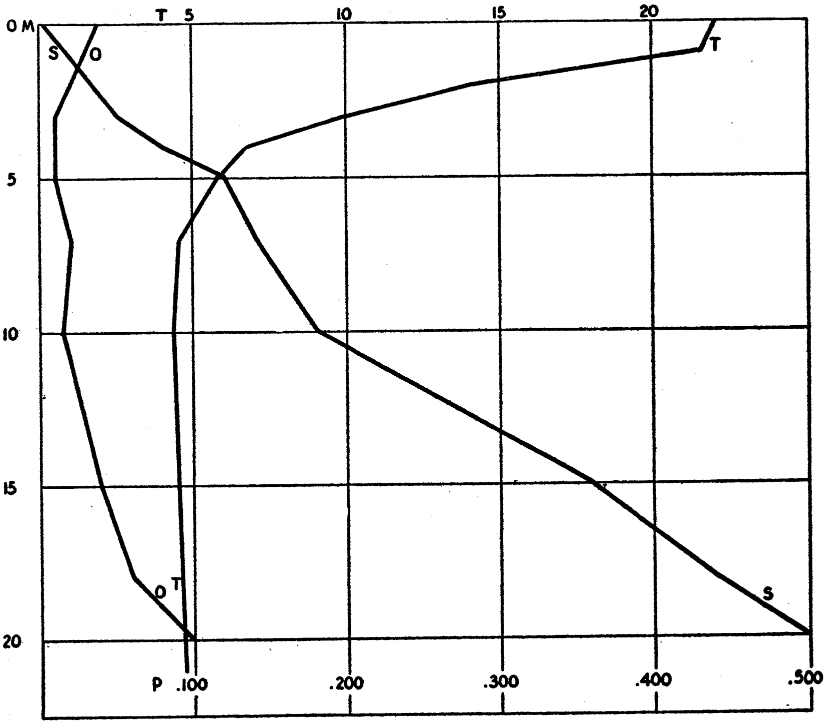

FIG. 7. Vertical distribution of phosphorus and temperature in Lake Mary, July 29, 1927. The phosphorus scale in this diagram is twenty times as large as that in the other diagrams. See fig. 2 for further explanations.

Vertical distribution. The vertical distribution of the organic phosphorus has been studied in 70 different lakes which range in maximum depth from 4 m. to 35 m. The observations comprise 165 series of three or more samples covering the entire depth of 65 lakes and 9 series of surface and bottom samples obtained from 5 of the shallower lakes.

Of the group of lakes from which only surface and bottom samples were obtained, Jag Lake had the same amount at surface and bottom (4 m.), namely 0.008 mg. of organic phosphorus per liter of water. In Little Crooked Lake the surface water contained 0.024 mg. and the bottom water (7 m.) 0.026 mg. In Little John Lake, with a maximum depth of 7 m., the average was 0.013 mg. for the surface and 0.023 mg. for the bottom. In Little John Jr., depth 9 m., the average of two series was 0.014 mg. and 0.025 mg. Little Star Bog, with a maximum depth of 5 m., gave a surface average of 0.017 mg. and a bottom average of 0.030 mg. per liter.

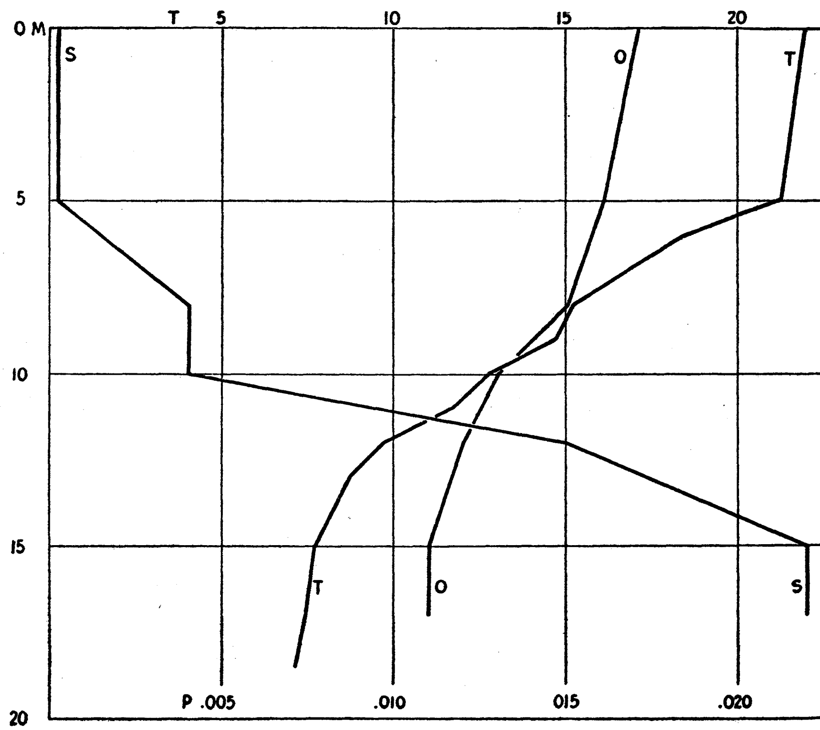

FIG. 8. Vertical distribution of phosphorus and temperature in Big Lake, July 21, 1928. See fig. 2 for further explanations.

The 165 series in which three or more samples were taken for each set readily fall into three groups on the basis of the vertical distribution of the organic phosphorus. A substantially uniform amount of organic phosphorus was found in the first group; in the second group there was a more or less marked increase of the organic phosphorus with increasing depth and in the third group there was a smaller amount in the lower water than in the strata above. Examples of the first and second groups are shown in figures 2 to 7 inclusive.

Three series of observations belong to the first group. In Crystal Lake (fig. 2) the amount of organic phosphorus was a little larger at the surface than at any other depth, but it was uniform from 5 m. to the bottom (19 m.). A substantially uniform distribution was also found in Lake Laura (12 m. deep) and in Wolf Lake (11.5 m. deep).

Figures 3 and 4, representing Little Trout and Clear lakes, show a larger amount of organic phosphorus at the bottom than at the surface. In the former lake the amounts were 0.013 mg. at the surface and 0.014 mg. at the bottom (26 m.), but 0.015 mg. per liter was noted at 20 m. In Clear Lake (fig. 4) on the other hand, there was a regular increase from surface to bottom; the quantity of organic phosphorus rose from 0.008 mg. at the surface to 0.016 mg. per liter at 25 m.

In Adelaide Lake (fig. 6) there was a marked increase of organic phosphorus in the lower water, but there was a somewhat smaller amount at intermediate depths than at either the surface or the bottom. The same was true of Little Tomahawk Lake on August 15, 1928; the quantity was smaller at 5 m. and 8 m. than at the surface and at 10 m. In Trout Lake (fig. 5) the decrease came between 15 m. and 28 m., but there was a marked rise at 31 m. The most marked difference between the surface and bottom, and the intermediate depths was found in Lake Mary. (See table II and fig. 7). The quantity of organic phosphorus declined from 0.037 mg. per liter at the surface to 0.010 mg. at 3 m. and 5 m. and then rose in the lower water to a maximum of 0.100 mg. per liter at 20 m. Similar results were obtained on Lake Mary in 1928 and 1929; a minimum of 0.010 mg. per liter was found at 5 m. in both of these years, with larger amounts above and below this depth. In 17 series of samples from 14 different lakes a smaller amount of organic phosphorus was obtained at some of the intermediate depths than at the surface and bottom. In four of these series there was a fairly close correlation between the changes in the quantity of organic phosphorus at the different depths and similar changes in the amount of organic carbon at the same depths, but there was no correlation between the variations in the quantities of organic phosphorus and organic carbon in the other thirteen series. The explanation of the latter variations must await a further study of the problem.

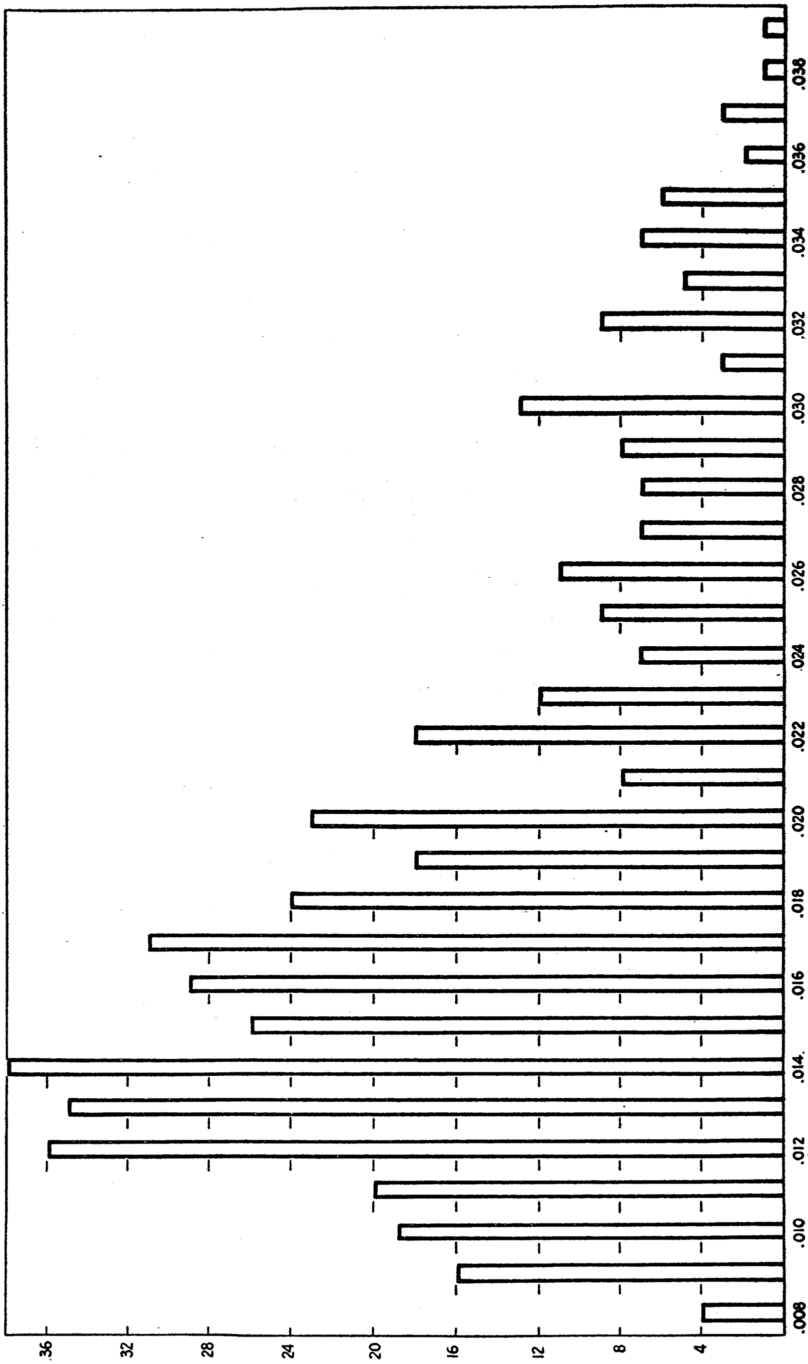

FIG. 9. This diagram shows the grouping of 454 lakes on the basis of the quantity of organic phosphorus found in their surface waters. Note that they cover a much wider range than in the diagram for soluble phosphorus (fig. 1). The vertical spaces represent the number of lakes in each group.

In the third group of serial samples, there was a smaller amount of organic phosphorus at the bottom than at the surface; this group is represented by nine series obtained from nine different lakes. The differences between surface and bottom range from a minimum of 0.002 mg. to a maximum of 0.014 mg. per liter; the average difference for the nine series is a little more than 0.006 mg. per liter. Figure 8, representing Big Lake, is a good example of this type of vertical distribution of the organic phosphorus. In this lake the organic phosphorus declined from 0.017 mg. at the surface to 0.011 mg. per liter at the bottom (17 m.).

TOTAL PHOSPHORUS

The total phosphorus is involved in the discussion of the soluble and of the organic phosphorus, so that it needs only a brief consideration. In the surface samples from the various lakes, the total phosphorus varied from a minimum of 0.008 mg. in Silver Lake at Rhinelander to a maximum of 0.140 mg. per liter in Little Star Lake. In the great majority of the lakes the quantity of total phosphorus in the surface water ranged from 0.015 to 0.030 mg. per liter; only four lakes showed 0.010 mg. or less. The second largest amount (0.110 mg.) was found in Eagle Lake and the third largest (0.100 mg.) in Summit Lake. In the surface samples from 11 different lakes the total phosphorus reached 0.060 mg. per liter or more. The largest amounts in the surface water were found in lakes which supported large growths of phytoplankton. The average amount of total phosphorus was somewhat larger in lakes with high colored waters, and this seems to indicate that the vegetable extractives responsible for the color carry a certain amount of phosphorus. The mean quantity of total phosphorus in the surface water of 479 lakes is 0.023 mg. per liter.

Hydrographic surveys of 20 of these lakes were made during the summer of 1930 and their volumes have been computed. This makes it possible to ascertain the approximate quantity of phosphorus in the various lakes. The results of these computations are shown in table III. The quantities of phosphorus given in the table are based on the average amount of this element in the surface water of each lake. No attempt has been made to compute the quantity in the separate strata of the various lakes because there are considerable variations in the amounts found

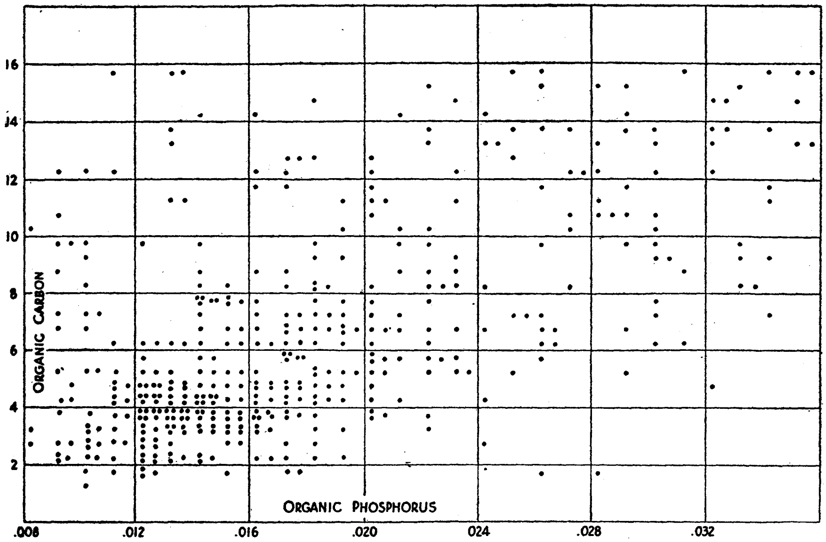

FIG. 10. **This diagram shows the relation between the organic phosphorus and the organic carbon in the surface waters of the various lakes. Each dot represents the observations on a single lake. The wide range of variation shows that the organic matter of the various lakes contains very different percentages of phosphorus.**

in the different strata in different years. This table shows that the smaller lakes possess only a few kilograms of phosphorus in the entire lake; in these cases it will be possible to increase the phosphorus content of the whole body of water through the use of phosphate fertilizers and thus study the effect of such fertilizers upon the growth of the phytoplankton. Plans are now being formulated for such experimental studies.

Vertical distribution. In a few of the vertical series of samples the total phosphorus was found to be uniformly distributed from surface to bottom. In Crystal Lake for example, the same amount of total phosphorus was present at all depths on August 17, 1926, namely 0.015 mg. per liter and a similar series was obtained in this lake on August 28, 1928, the amount on the latter date being 0.012 mg. per liter at all depths.

The great majority of the serial observations showed a more or less marked increase in the quantity of total phosphorus with increasing depth. (See table II). In some instances this increase was due to the presence of a larger amount of soluble phosphorus in the lower water, but in most cases it was due to increases in both the soluble and the organic phosphorus. The largest increase in the lower water was found in Lake Mary; table II shows 0.600 mg. of total phosphorus at 20 m. on July 29, 1927 and a larger amount was found at this depth on July 12, 1926, namely 0.750 mg. per liter. In 25 lakes on which serial observations were made, the lower water contained more than 0.050 mg. of total phosphorus per liter, while in 43 lakes the quantity did not exceed this amount.

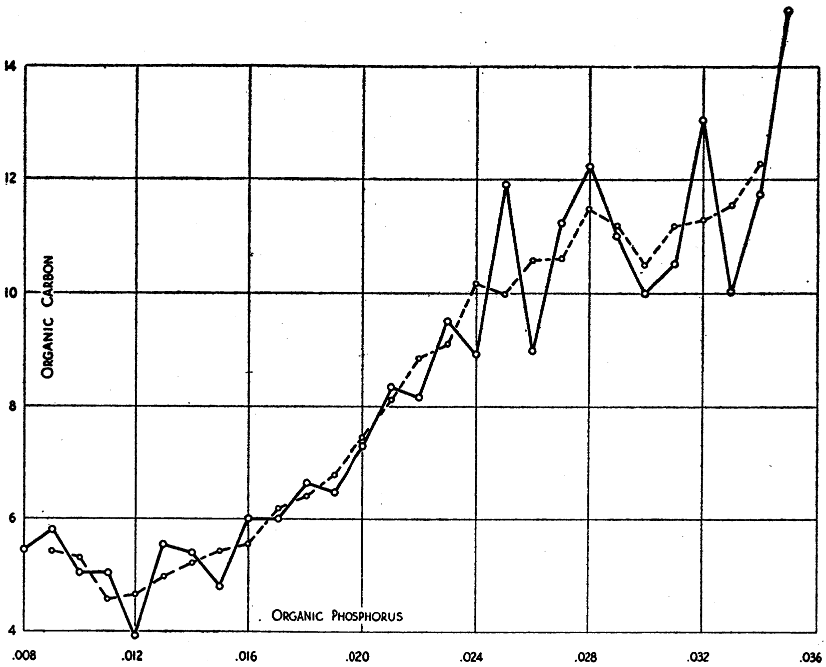

FIG. 11. In this diagram the mean quantity of organic carbon in the different phosphorus columns of fig. 10 are platted against the amount of organic phosphorus represented by the corresponding columns. The solid line represents the actual means of the different organic phosphorus columns and the broken line represents the running mean of three columns.

DISCUSSION OF RESULTS

The production of aquatic plants by a body of water is dependent upon the presence of certain dissolved substances in an available form, such as nitrogen, potassium and phosphorus. This is especially true of the phytoplankton since it is made up of free floating organisms that depend entirely upon these dissolved substances in the upper water for their food materials.

Nitrogen and potassium are usually present in natural waters in sufficient amounts to supply the needs of these organisms, but the phosphorus supply in the lakes under consideration is very limited and it may have some effect upon the productivity of some or all of these bodies of water. Light is also a necessary factor in the process of photosynthesis, so that the actively growing phytoplankton is confined chiefly to the upper stratum of water or the epilimnion of stratified lakes where enough solar energy is present to enable these organisms to carry on photosynthesis . This means, therefore, that the principal demand for these plant foods is confined to the upper stratum of water.

Some of these phytoplankton organisms as well as some of the zooplankton forms that feed on them, are constantly dying and sinking into the lower water, thereby transferring the food materials derived from the upper stratum to the lower water of a lake. As these dead organisms sink into the lower water, they pass through some of the early stages of decomposition at least, while the later stages take place on or near the bottom. In a stratified lake the materials transferred in this manner remain in the lower stratum until the autumn overturning of the water distributes them uniformly from surface to bottom. In the process of decomposition the phosphorus constituent of these organic compounds is changed from the organic to the phosphate or soluble form and this process is called regeneration; it is the reverse of what takes place in the upper water.

Table IV shows the phosphorus content of plankton material obtained from 10 of these lakes. The crustacea in some instances contained rather large amounts of this element; the maximum percentage was found in a tow net catch from Trout Lake which consisted chiefly of crustacea. Algae are the chief constituents of the centrifuge plankton and the Anabaena catch from Trout Lake contained substantially the same percentage of phosphorus as the centrifuge material from that lake. The last column in table IV shows that the quantity of phosphorus in the centrifuge plankton ranged from 0.003 mg. to 0.016 mg. per liter of water. It is evident from these results that any extensive transfer of plankton material from the upper water to the lower strata will make a material contribution to the phosphorus content of the latter.

Some of these organisms undergo decomposition in the upper water of a stratified lake and the final products of this process become available immediately for further plant growth. This is true also of a lake which is so shallow that the entire body of water is kept in circulation during the summer. In such lakes these food materials may be used repeatedly during the course of the growing season. Where these substances are scarce, the shallow lake thus has a decided advantage over one that is deep enough to be stratified.

Whether the soluble and organic phosphorus increase in quantity in the lower water of a stratified lake during the summer depends chiefly upon the abundance of the plankton and the rate of decomposition in the lower stratum. In a lake that is poor in plankton, such as Crystal (fig. 2) for example, there is no increase of soluble or organic phosphorus in the lower water during the summer. In lakes that support a larger growth of plankton, on the other hand, there is a more or less marked increase of phosphorus, either soluble or organic or both, in the lower stratum during the summer period of stratification; this is the most common type of stratified lake. Such conditions are shown in figures 4 to 7; Lake Mary is an extreme example of this type.

The quantity of organic phosphorus that accumulates in the lower water of a stratified lake in summer depends upon the amount of organic material that sinks into this stratum and also upon the rate of decomposition. In some instances decomposition proceeds rapidly enough to prevent the accumulation of organic phosphorus in the lower water. The surface water of Catfish Lake, for example, contained 0.013 mg. of organic phosphorus per liter on July 31, 1928 and the bottom water (22 m.) yielded the same amount; the soluble phosphorus, on the other hand, rose from 0.003 mg. at the surface to 0.022 mg. per liter at 22 m. Crooked Lake also showed the same amount of organic phosphorus, namely 0.010 mg. per liter, at surface and bottom (21 m.) on August 10, 1928, while the soluble phosphorus increased from a trace at the surface to 0.005 mg. at the bottom. In these instances, therefore, it appears that the process of decomposition went on rapidly enough to prevent an increase of the organic phosphorus in the lower water, but there was an increase of soluble phosphorus due to the conversion of the organic phosphorus into the soluble form.

In some of the lakes decomposition proceeded fast enough in the lower water to reduce the quantity of organic phosphorus in that stratum below that at the surface. These lakes constitute the third group mentioned in connection with the vertical distribution of the organic phosphorus. In a set of samples taken on Big Lake (fig. 8) on July 21, 1928, the surface water yielded 0.017 mg. of organic phosphorus per liter and the bottom sample (17 m.) contained only 0.011 mg.; the quantity of soluble phosphorus at these same depths was a trace and 0.022 mg. per liter respectively. On August 23, 1928 the surface water of Long Lake yielded 0.015 mg. of organic phosphorus per liter and the bottom sample (12 m.) 0.010 mg.; the soluble phosphorus at these depths was 0.003 mg. and 0.090 mg. respectively. While the quantity of organic phosphorus was smaller at the bottom than at the surface, the difference was more than compensated for by the soluble phosphorus, so that the total phosphorus was much larger at the bottom than at the surface.

The utilization of the soluble phosphorus of the upper water by the phytoplankton and the subsequent transfer of some of these organisms to the lower strata when they die, ought to produce a more or less marked decrease of the phosphate in the upper stratum during the summer period. In about half of the lakes on which spring and summer observations were made there was such a decrease of the soluble phosphorus in the upper water, but in the other half the quantity was either the same in the summer as in the spring or a somewhat larger amount was present in the former than in the latter season. In some of the latter lakes the quantity of soluble phosphorus was maintained or was even increased somewhat during the growing season in spite of the fact that these bodies of water sustained a relatively large growth of phytoplankton.

In spite of the various physical, chemical and biological processes which tend to keep the phosphorus in the lake water either in a soluble or an organic form, a certain amount of it is lost to the deposits that are formed on the bottom. Black (1929) found, for example, that the percentage of the element phosphorus in dry samples of these lake deposits ranged from 0.07 per cent in Silver Lake to 0.63 per cent in Star Lake.

SUMMARY

1. The phosphorus content of 479 lakes of northeastern Wisconsin has been determined.

2. The mean quantity of soluble phosphorus in the surface water of the various lakes is 0.003 mg. per liter; the range is from none in nine lakes to a maximum of 0.015 mg. in one.

3. In 54 pairs of spring and summer observations on the surface water of 32 lakes, 26 pairs showed a smaller amount of soluble phosphorus in summer than in spring, 12 pairs were the same, and 16 pairs yielded a larger amount in summer than in spring. In the second and third groups, the soluble phosphorus was maintained at the spring level, or even increased somewhat, during the summer in spite of the fact that some of these lakes supported large crops of phytoplankton at that time.

4. Most of the thermally stratified lakes showed a more or less marked increase in the quantity of soluble phosphorus in the lower strata in summer.

5. The mean quantity of organic phosphorus in the surface water of these lakes is 0.020 mg. per liter; the range is from 0.005 mg. to 0.103 mg. per liter.

6. On the basis of the vertical distribution of the organic phosphorus, the various series of samples may be divided into three groups; (a) those with the same quantity of organic phosphorus at the surface and the bottom, (b) those with a larger amount at the bottom than at the surface, and (c) those with a smaller amount at the bottom than at the surface.

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Juday, C., E. A. Birge, G. I. Kemmerer and R. J. Robinson. Phosphorus content of lake waters of northeastern Wisconsin. Trans. Wis. Acad. Sci., Arts & Let. 23 : 233–248. 1928.

Robinson, Rex J. and George Kemmerer. Determination of organic phosphorus in lake waters. Trans. Wis. Acad. Sci., Arts & Let. 25: 117–121. 1930.

TABLE I. *This table shows the phosphorus content of the waters of 19 wells and one spring. The results for total phosphorus are indicated in fractions of a milligram per liter of water.*

Lake	Well	Date	Phosphorus
Arbor Vitae	Big Arbor Vitae Resort	August 17, 1930	0.197
Big Bass	Big Bass Resort	August 12, 1930	0.050
Black Oak	Goodnight Handlos St. Clair Woodhall	August 15, 1930 August 27, 1930 August 27, 1930 August 27, 1930	0.019 0.017 0.009 0.006
Blue	Blue Lake Resort	August 14, 1930	0.007
Brandy	Brandy Lake Resort	August 14, 1930	0.005
Forest	Forest Lake Home	August 27, 1930	0.006
Little Bass	Anderson	August 14, 1930	0.002
Little Papoose	Spring	August 23, 1930	0.016
Mamie	Bent	August 27, 1930	0.086
Mercer	Mercer	August 16, 1930	0.012
Papoose	Graham	August 23, 1930	0.006
Payment	Payment	August 16, 1930	0.009
Tenderfoot	Gillen	August 27, 1930	0.032
Trout	Barn Laboratory Mc Clain Smith	August 15, 1930 August 29, 1930 August 23, 1930 August 23, 1930	0.034 0.010 0.007 0.022

TABLE II. *The quantity of fixed carbon dioxide, phosphorus, plankton, and organic carbon found in 25 lakes of northeastern Wisconsin in 1927. The results are stated in milligrams per liter of water. The plankton results show only the amount of organic matter in this material. Tr. means trace.*

Lake	Date	Depth in Meters	Fixed Carbon Dioxide	Phosphorus			Plankton	Organic Carbon
				Soluble	Organic	Total		
Adelaide	May 7	0	3.0	0.007	0.020	0.027	1.34	8.1
	August 5	0	2.6	0.003	0.009	0.012	1.54	9.3
		5	2.6	0.004	0.008	0.012	1.32	8.0
		10	3.1	0.006	0.007	0.013	0.93	7.0
		15	3.4	0.012	0.009	0.021	0.98	9.5
		20	4.4	0.021	0.017	0.038	1.28	10.0
Allequash	May 5	0	14.5	0.007	0.013	0.020	1.32	6.0
	June 25	0	15.8	0.004	0.029	0.033	1.21	6.4
Arbor Vitae	May 4	0	22.1	0.007	0.019	0.026	2.34	3.6
	July 7	0	22.0	0.007	0.015	0.022	1.39	4.7
Bass	May 3	0	1.4	0.006	0.016	0.022	0.88	2.7
	August 14	0	1.3	0.005	0.014	0.019	0.96	2.4
Big Carr	May 6	0	1.0	0.005	0.017	0.022	1.16	3.0
	July 18	0	1.4	0.005	0.010	0.015	0.54	3.3
		5	1.4	0.005	0.013	0.018	0.56	3.4
		10	1.5	0.005	0.014	0.019	0.92	3.3
		15	1.5	0.007	0.013	0.020	0.62	3.0
		21	1.8	0.009	0.018	0.027	0.93	3.5
Big St. Germaine	May 4	0	14.4	0.008	0.016	0.024	1.57	7.3
	July 7	0	14.9	0.006	0.026	0.032	1.43	6.0
Black Oak	May 8	0	9.7	0.006	0.011	0.017	1.58	4.3
	August 15	0	8.8	0.004	0.013	0.017	0.63	4.4
		8	8.8	0.004	0.014	0.018	-----	-----
		10	8.8	0.004	0.016	0.020	0.85	3.7
		18	8.8	0.005	0.017	0.022	0.94	3.3
		24	11.4	0.095	0.015	0.110	1.42	4.1
Blue	May 2	0	9.3	0.005	0.010	0.015	1.48	4.1
	July 8	0	9.0	0.007	0.012	0.019	0.66	3.8
		5	9.2	0.007	0.011	0.018	0.75	3.9
		7	9.2	0.006	0.012	0.018	1.19	4.1
		10	9.6	0.006	0.016	0.022	0.96	4.6
		12	9.7	0.006	0.016	0.022	2.04	4.3
Clear	May 3	0	3.5	0.005	0.008	0.013	1.06	3.5
	July 27	0	3.5	0.005	0.007	0.012	0.65	3.2
		5	3.5	0.005	0.008	0.013		
		10	3.6	0.005	0.009	0.014	0.75	3.2
		15	3.6	0.005	0.009	0.014	0.69	3.2
		20	3.7	0.007	0.011	0.018	0.34	2.9
		25	4.1	0.012	0.016	0.028	0.49	3.1
Content	May 4	0	11.2	0.006	0.014	0.020	1.16	4.2
	July 7	0	11.1	0.007	0.015	0.022	0.46	4.1
Crystal	May 8	0	2.0	0.007	0.009	0.016	1.14	1.9
	July 1	0	1.2	0.005	0.009	0.014	0.27	1.4
		5		0.005	0.009	0.014		
		10	1.2	0.005	0.011	0.016	0.24	1.6
		15		0.004	0.014	0.018	0.34	1.8
		18	1.2	0.004	0.014	0.018	0.45	2.1
Forest	May 8	0	10.8	0.007	0.012	0.019	1.77	4.3
	August 14	0	10.3	0.003	0.021	0.024	1.19	5.3
Helen	May 7	0	2.6	0.008	0.025	0.033	1.79	13.8
	July 10	0	2.7	0.004	0.026	0.030	1.26	11.0
Island	May 8	0	1.1	0.006	0.008	0.014	0.55	1.9
	August 14	0	1.3	0.004	0.012	0.016	0.50	1.9

TABLE II—Continued

Lake	Date	Depth in Meters	Fixed Carbon Dioxide	Phosphorus			Plank-ton	Organic Carbon
				Soluble	Organic	Total		
Kawaguesaga...	May 2	0	20.8	0.005	0.019	0.024	1.64	4.0
	June 29	0	19.3	0.005	0.013	0.018	1.01	4.3
Little Arbor Vitae........	May 4	0	21.5	0.007	0.021	0.028	3.20	6.3
	July 7	0	22.7	0.009	0.028	0.037	1.26	6.4
Little Carr......	May 6	0	0.8	0.008	0.014	0.022	1.20	3.1
	June 30	0	1.4	0.005	0.013	0.018	0.76	3.4
Little John.....	May 8	0	15.8	0.007	0.014	0.021	2.32	5.0
	July 12	0	17.2	0.007	0.014	0.021	0.88	4.5
Little Star......	May 3	0	8.8	0.005	0.015	0.020	2.08	3.9
	July 16	0	8.7	0.005	0.016	0.021	0.56	4.6
Little Tomahawk........	May 6	0	19.3	0.008	0.012	0.020	0.79	3.4
	July 25	0	19.5	0.005	0.013	0.018	0.90	4.1
		7	19.8	0.005	0.013	0.018	1.08	4.1
		10	21.1	0.005	0.015	0.020	0.92	3.5
		14	23.7	0.009	0.016	0.025	0.72	3.6
Madeline.......	May 3	0	20.3	0.006	0.014	0.020	2.62	4.2
	August 13	0	18.3	0.004	0.021	0.025	0.88	5.7
Mann..........	May 5	0	22.0	0.005	0.016	0.021	3.00	4.7
	August 26	0	25.6	0.005	0.037	0.042	8.86	11.1
Mary..........	May 7	0	2.5	0.015	0.038	0.053	1.64	17.3
		20	9.0	0.400	0.070	0.470	0.81	22.9
	July 29	0	2.5	0.003	0.037	0.040	1.76	17.8
		3	2.7	0.050	0.010	0.060	1.84	17.0
		5	4.7	0.120	0.010	0.130	2.00	16.1
		10	5.7	0.180	0.015	0.195	1.95	18.6
		15	8.7	0.360	0.040	0.400	1.02	17.4
		18	10.3	0.440	0.060	0.500	1.33	21.8
		20	11.5	0.500	0.100	0.600	1.92	22.8
Muskellunge....	May 8	0	9.2	0.007	0.011	0.018	1.27	4.4
	July 2	0	8.9	0.006	0.014	0.020	1.32	4.0
		5	9.0	0.006	0.014	0.020	1.28	4.1
		10	9.0	0.006	0.016	0.022	1.49	4.0
		15	9.0	0.006	0.028	0.034	1.30	3.8
		18	9.8	0.006	0.028	0.034	1.05	4.6
Silver..........	May 7	0	15.4	0.005	0.015	0.020	0.95	2.9
	July 7	0	15.2	0.006	0.009	0.015	0.54	3.5
		5	15.3	0.006	0.009	0.015	0.58	3.5
		10	15.3	0.006	0.012	0.018	0.56	3.3
		13	15.5	0.006	0.012	0.018	0.86	3.3
		17	15.8	0.012	0.016	0.028	0.94	3.3
Tomahawk.....	May 6	0	16.5	0.006	0.014	0.020	1.22	3.2
	July 26	0	17.3	0.005	0.015	0.020	0.53	3.2
		5	17.3	0.005	0.015	0.020	0.72	3.5
		10	17.5	0.005	0.017	0.022	0.77	3.4
		15	18.3	0.009	0.015	0.024	0.52	3.3
		18	18.6	0.013	0.025	0.038		
		21	19.0	0.019	0.021	0.040	0.72	3.3
Trout..........	May 5	0	18.5	0.006	0.012	0.018	0.94	4.1
		30	18.5	0.006	0.014	0.020	1.24	3.6
	August 20	0	19.0	0.003	0.015	0.018	1.10	3.9
		5	19.0	0.003	0.017	0.020	0.90	4.2
		10	19.0	0.003	0.017	0.020	0.87	4.1
		15	19.0	0.003	0.017	0.020	0.82	3.5
		20	19.0	0.005	0.015	0.020	0.58	3.7
		25	19.0	0.008	0.012	0.020	0.65	3.6
		31	20.2	0.008	0.025	0.033	1.18	3.6
Turtle..........	May 7	0	12.0	0.006	0.021	0.027	1.95	14.1
	July 22	0	11.6	0.007	0.016	0.023	0.71	13.6
		5	11.6	0.007	0.013	0.020	0.64	13.6
		8	11.6	0.007	0.016	0.023	0.46	13.8
		12	12.2	0.014	0.028	0.042	0.54	13.2

TABLE II—Continued

Lake	Date	Depth in Meters	Fixed Carbon Dioxide	Phosphorus			Plank-ton	Organic Carbon
				Soluble	Organic	Total		
Upper Kaba-sheen........	July 11	0	18.3	0.007	0.015	0.022	0.40	4.0
		5	18.3	0.007	0.015	0.022	0.49	3.2
		10	20.0	0.010	0.020	0.030	0.64	3.5
		13	20.1	0.040	0.020	0.060	1.09	4.1
		16	21.2	0.190	0.010	0.200	1.24	4.1
Weber..........	May 8	0	1.0	0.007	0.010	0.017	0.88	2.1
	July 13	0	0.9	0.005	0.009	0.014	0.22	1.7
		8	1.3	0.005	0.009	0.014	0.42	2.2
		10	1.3	0.006	0.010	0.016		
		12	1.5	0.008	0.012	0.020	0.78	2.0

TABLE III. *Quantity of phosphorus in 19 lakes situated in northeastern Wisconsin.*

Lake	Volume in cubic meters	Milligrams of total phosphorus per cubic meter	Kilograms of phosphorus in entire lake
Adelaide	1,480,000	20.5	30.3
Big Carr	8,880,000	16.0	142.1
Black Oak	23,302,000	16.6	386.6
Bragonier	664,000	21.2	14.1
Crystal	2,864,000	13.5	38.7
Diamond	3,384,000	13.2	44.8
Finley	3,408,000	17.2	58.8
Helen	261,000	32.5	8.5
Hillis	179,000	13.0	2.3
Little Bass	358,000	14.0	5.0
Little Long	1,229,000	25.0	30.7
Mary	102,000	40.4	4.1
Midge	153,000	20.0	3.1
Pauto	718,000	15.0	10.8
Rose	73,000	35.0	2.6
Silver	9,883,000	16.6	164.1
Weber	1,132,000	13.1	14.8
White Sand	19,275,000	14.7	283.3
Yolanda	66,700	31.0	2.1

TABLE IV. *The phosphorus content of plankton organisms obtained from lakes of northeastern Wisconsin. The results are stated in percentages of the dry weight of the material and in milligrams per liter of water for the centrifuge plankton. The tow net catches are not quantitative.*

Lake	Date	Organism	Per cent of phosphorus	Milligrams of phosphorus per liter of water
Bear	July 11, 1930	Centrifuge plankton	0.311	0.0047
Boulder	June 28, 1927	Tow net—Crustacea	0.449	
Clear	July 27, 1927	Tow net—Crustacea	0.185	
	July 27, 1927	Centrifuge plankton	0.180	0.0027
Crystal	July 12, 1927	Tow net—Crustacea	0.604	
Jag	July 7, 1928	Volvox	0.598	
Lower Gresham	July 29, 1930	Centrifuge plankton	0.394	0.0160
Papoose	August 2, 1928	Tow net—Crustacea	0.629	
Trout	August 20, 1927	Tow net—Crustacea	0.712	
	August 24, 1927	Centrifuge plankton	0.275	0.0043
	July 7, 1930	Anabaena	0.235	
Turtle	July 27, 1928	Tow net—Crustacea	0.173	
Wild Cat	June 26, 1927	Tow net—Crustacea	0.319	
	August 28, 1927	Centrifuge plankton	0.290	0.0091

A THIRD REPORT ON SOLAR RADIATION AND INLAND LAKES

E. A. BIRGE AND C. JUDAY

Notes from the Limnological Laboratory of the Wisconsin Geological and Natural History Survey. No. XLIII.

The first paper of this series ('29) on solar radiation and inland lakes reported on the quantity of radiation to be found at different depths in these lakes and on its percentile transmission through the water. The second paper ('30) continued this part of the study and enlarged its scope by furnishing data on the transmission of the several colors of the spectrum. In the summer of 1930 both phases of the investigation were continued by observations in the lakes of Northeastern Wisconsin; and there was added a quantitative study of the composition of the radiation present in the lakes and of the changes in that composition as radiation passes through the water. The present paper reports on the last matter only; consideration of transmission of radiation, etc., being left to the future.

SUMMARY

1. The quantity of solar radiation found in lakes at the depth of 1 m. or more is observed and computed as stated in our former papers ('30:289).

2. At these depths the energy spectrum extends little if at all beyond the limits of the visible spectrum and the study is practically concerned with light.

3. By the use of a series of light-filters with the pyrlimnometer, data are secured from which percentile cumulative curves of the spectrum may be constructed. These represent the distribution of the radiation in the spectrum. See fig. 9 and others.

4. From these curves is derived that per cent of the total radiation which is to be found in any region of the spectrum, whether this is defined by wave-length or by color. See fig. 10 and others.

5. This distribution is of various types dependent primarily on the relation between wave-length of radiation and its transmission through water. The facts are further complicated by effects due to stains dissolved in the water and by suspended matters. These results may be expressed in quantitative terms, either as a per cent of the total radiation; or in definite units by combining these data with those derived as stated under 1.

6. Associated with increase of depth of water are changes in composition of radiation due to causes named under 5. These also are quantitatively expressed. See figs. 13, 14, and others.

7. In general, the pyrlimnometer enables us to follow these changes through the epilimnion of inland lakes. It furnishes a quantitative analysis of the radiation derived from the several regions of the spectrum, and gives a quantitative basis for the study of the relation between light and organisms in this region of the lakes. In the more transparent lakes the study may be extended to regions below the epilimnion.

Instruments and their Use

The Pyrlimnometers. The pyrlimnometer used in 1929 has been figured and briefly described (Birge and Juday, '30:287). This instrument was continued in use during 1930; but the main work of that season was on the composition of the spectrum and called for a larger number of light-filters, so that another and larger machine was built. Its general construction is entirely like that of the first one, differing only in unimportant details. The carriers for light-filters — called plates — in the model of 1930 have openings for eight filters, while those of the earlier model are adapted for five filters; their diameters are 18 cm. and 25 cm. The frame of the 1929 model is 50 cm. long and 15 cm. wide; that of the later model measures 56 cm. by 20 cm. Their weights are 3 kg. and 5 kg., respectively.

The Thermopile. The central part of the instrument is the thermopile. This is a large surface Moll thermopile made by Kipp & Sons, of Delft, Holland, containing 80 elements on a circular surface 20 mm. in diameter. For our use it is mounted in a brass case 65 mm. in diameter. The opening over the thermopile is 35 mm. in diameter and a plate glass cover is cemented into it. A recess on one side of the cavity for the

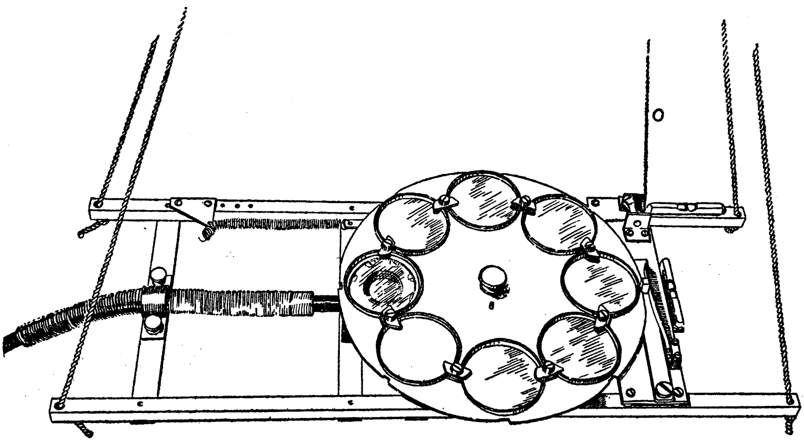

FIG. 1. Pyrlimnometer, form of 1930, with plate carrying 8 filters. Moll thermopile is seen in place, in the opening of the plate occupied by filter GG-1. The next opening—below in figure—holds the white opaque disc; then follow the filters in the order listed for plate 1 on p. 390. The operating cord is seen at O: a pull on this brings the opaque disc over the thermopile. Note milled head of screw which fastens plate to ratchet-wheel below it (see fig. 2) also small peg projecting through plate, which ensures fixed position of plate. Compare fig. 1 in Birge and Juday '30.

thermopile contains some phosphorus pentoxide. An insulated cable 20 m. or more in length is connected with the thermopile; its entry into the box is carefully sealed, and a spring-like coil of wire is wrapped about the cable near the junction with the box, in order to prevent sharp bending at this point.

The Filter-carriers or Plates. The diameter of the light-filters and the consequent size of the plates that carry them were determined by the size of the bismuth-silver thermopile used in earlier studies. The area of this thermopile was much larger than that of the Moll instrument and called for larger filters. The earlier filters were Wratten filters—gelatine films cemented between discs of optical glass—and with their frames are about 60 mm. in diameter and 5 mm. thick. The details of the plates are therefore different from those which are adapted for use with the Moll thermopile and the filters of Jena glass, but the general plan would not be altered. The change in thermopile and filters made no difference in the operation of the pyrlimnometer. The Jena filters are 59 mm. in diameter and in general 2 mm. thick.

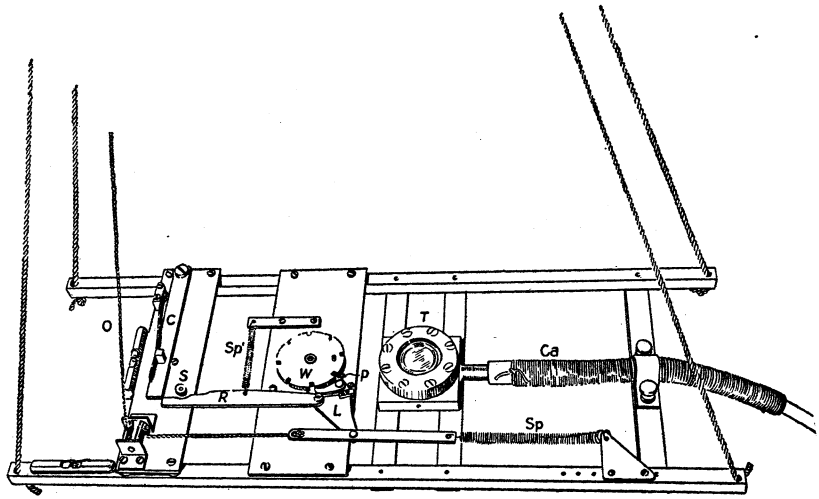

FIG. 2. Operating mechanism of pyrlimnometer, in position of rest.

C, bar carrying catch which holds filter-plate in place; it is pivoted on screw seen at its upper end in figure. Catch is held against edge of plate by a spring. Note this part of mechanism in fig. 1.

L, Operating lever, a flat plate which turns on the socket of W; it carries the pawl, *P*. Note position of P relative to notch of ratchet-wheel. L is moved by a bar to one end of which is attached the operating cord O and to the other the return spring, Sp.

O, operating cord, passing under a pulley and connecting with L.

R, release bar of catch; one end attached to L and moving with it; the other bearing against release bar of catch, C. R normally rests against the stem of S, lying under its head. It has been drawn away from this to show the curved form of its side, which is an important element in the mechanism.

Sp, return spring of mechanism.

Sp[1], spring of release bar.

S, stop of release bar, against which it is held by spring Sp[1].

T, thermopile, with insulated cable, *Ca*.

W, ratchet-wheel for carrying filter plate; its axle goes into a socket below the frame. Note 8 notches corresponding to the openings of the plate.

A pull on the operating cord rotates the lever L and moves forward the release bar R. The first effect is that R pushes the catch C out of the notch in the edge of the filter-plate, which thus becomes free to turn; then the pawl P engages with the notch in the ratchet-wheel and begins to rotate the plate. Meanwhile as the release bar R advances, its curved side bearing against S, is pushing it along toward the end of the bar C. As soon as the filter-plate has advanced enough to move its notch away from the catch, R has been pushed off the end of C and is free to move past it. The catch springs back against the edge of the plate, ready to engage the next notch when it comes around. Rotation of filter-plate continues until plate is stopped and held by catch falling into notch. Then operating cord is released, spring Sp draws back the whole mechanism; Sp^1 brings the release bar back to its place against the stem of S; and the apparatus is ready for the next advance. Note that the catch is square in section; the notch of the plate which it enters is of the same shape and but little larger; so that the plate is held firmly with the filter centered over the thermopile.

Experiments to determine the necessary diameter of the filters have been made with diaphragms of thin sheet brass. These have clear openings of 32 mm. and 42 mm., respectively, while the clear opening of the present plates is 53 mm. It was found that the smaller openings did not cause any reduction of the readings of the thermopile at any altitudes of the sun at which work was done, or is likely to be done during our summers. A corresponding reduction of the diameter of the filters would allow 8 openings in the plate of the small pyrlimnometer and would make unnecessary the enlargement of the instrument. Such a change would be an improvement.

The plates are made of brass about 1.5 mm. thick and either 18 cm. or 25 cm. in diameter. The edge of the plates has notches for the catch which holds each successive filter in place as rotation brings it above the thermopile. Each filter is kept in its socket by small projecting pieces of brass held down by screws; this arrangement is based on the needs of the Wratten filters and can easily be improved if Jena filters are used.

The mechanism for rotating the plate and bringing the successive filters above the thermopile is the device of Mr. J. P. Foerst, mechanician of the department of physics, University of Wisconsin. It is efficient, simple and as nearly "fool-proof" as such a mechanism can be. It is figured and described in fig. 2.

The Recording Instruments. During 1930 the same recording instruments were used as in 1929. They are two millivoltmeters made by the Rawson Electrical Instrument Co. of Cambridge, Mass. The first has four ranges, its scale of 100 divisions corresponding to 20, 10, 5, and 2 mv., respectively; the second and more sensitive instrument is of the semi-suspended type and has two ranges, 2 mv. and 0.333 mv. The first millivoltmeter is used to determine the radiation in the air and in the water close to the surface of the lake. The 2 mv. range may be used at considerable depths, especially in transparent waters; but at depths of 1 m. or more, readings are usually made with the more sensitive meter, employing the 2 mv. or the 0.333 mv. range, as may be indicated. In this instrument the internal resistance of both ranges is the same and the scale-reading of the 0.333 mv. range is six times that of the 2 mv. range.

Both of these millivoltmeters are well suited to work of the type that we have undertaken, the study of radiation in the waters of small inland lakes, carried on by means of rowboats or small launches. The more sensitive instrument and range are quite as steady as the others and are read quite as easily and accurately. They do not need to be leveled and small irregular movements of the boat, due to waves, do not seriously disturb them. The needle is deflected from its proper resting place by a change in the average position of the boat, such as would be caused by a change of the position of an observer toward one side of the boat, and if the boat rolls in the trough of the waves the needle is set to swinging. In lakes like ours neither of these difficulties need arise. We have not tried the instruments in larger bodies of water, like the sea or one of the Great Lakes, where there is always a swell.

The rapidity of movement of the needle of the millivoltmeters varies with the sensitivity of the range, and in the 0.333 mv. range it is quite slow. Even a short swing takes 10-15 seconds and a large one covering much of the scale, may easily require 30-45 seconds. Movement is especially slow near the end of the swing, either when rising to the full reading or returning to the natural position of zero. Many seconds may be needed to make sure that the needle has returned to its exact position of rest.

Readings in the water were made with both the 2 mv. and the 0.333 mv. ranges, whenever the amplitude of the scale-reading permitted. This was done partly to check the readings and partly to keep ourselves assured of the constancy of the ratio between the scales.

The Light-filters. There were employed for the analysis of the radiation in the lakes a series of eleven light-filters of Jena glass, extending from GG-1 to RG-5 of the catalogue of the Jenaer Glaswerk, and completed by the Wratten filter 88a. These filters transmit the whole or almost the whole of the radiation contained in wave-lengths greater than the position of their cut-off and the position of the center of their cut-off is found at different wave-lengths from 3500 Å to 7500 Å. The situation is shown in fig. 8, which is a combined diagram modified from those given for single filters in the catalogue of Messrs. Schott and Co.

It should be noted that these filters do not necessarily agree with the data and the diagrams given in this catalogue. The different melts of glass give results which are not uniform, as is stated on p. 2 of the catalogue. The data on transmission given in the catalogue are not detailed enough for the sort of work to which we have put the filters and the Jenaer Glaswerk very kindly furnished us with detailed data for these filters, giving the transmission for intervals of 100 Å. Several of the filters came from melts of glass other than those used in the catalogue and their transmission was correspondingly different. Filter GG-5, for instance, proved to be very close to GG-7 and its readings had to be dropped from the series; the center of the cut-off for RG-1 and RG-2 proved to be closer together than would be inferred from the catalogue and the mean of the two readings was used and was platted at the suitable wave-length.

Fig. 8 shows that most of the cut-off of the several filters occupies a short distance in the spectrum. The filters from GG-1 to OG-2 inclusive transmit 100 per cent of the radiation from wave-lengths longer than the position of the cut-off; those marked RG transmit 96 to 98 per cent and the Wratten filter 88a transmits 87.5 per cent. The use of these filters began at the depth of one meter in the lake, where almost all of the infra-red and much of the red radiation has been absorbed. The differences in transmission, therefore, practically involved small quantities and no correction was made for them.

In general the readings of the several filters were platted at the wave-length where the line of the cut-off intersects the 50 per cent line of the diagram. This placed the filters as follows:

Filter	*Wave-Length*	*Filter*	*Wave-Length*
GG–1	3500 Å	OG–1	5250 Å
GG–2	3750	OG–2	5700
GG–3	4250	RG–1	6150
GG–7	4600	RG–2	6250
GG–11	4900	RG–5	6700
		W 88a	7500

Note: The mean value of readings from RG–1 and RG–2 was platted at 6200 Å.

The reading of GG–1 was taken as giving the full effect of the sun for purposes of this investigation. Numerous comparisons were made of readings taken with this filter and those taken without a filter or *open*. In almost all cases the reading without a filter was the larger, slightly above that with GG–1. In 31 comparisons made in 17 different lakes the average reading with GG–1 was 98.8 per cent of that with *open*; with a minimum of 92.6 per cent in one case and a maximum of 100 per cent in two cases. In Trout Lake a set of comparisons between GG–1 and *open* was made by 22 readings at depths from 1 to 4 meters. The maximum reading was 79 divisions of the scale at 1 m. and the minimum was 21 divisions at 4 m. In no case was the difference between GG-1 and *open* so large as one division of the scale. Differences of this order, and even much larger, may not uncommonly be present in readings taken in rapid succession with *open*; they are due to variations in the sun and in the suspended matter in the water. In this series the sun was fairly steady; it may also be noted that GG–1 was several times above *open*. GG–1 cuts off only the extreme ultraviolet, of which little or nothing is present in the water at the depth of 1 m. Since some effect from the glass surfaces is present in the readings from all filters it was decided to consider the reading from GG–1 as representing 100 per cent of the radiation and thus avoid the necessity of attempting to correct for the effect of the glass.

The series of filters was arranged for use in the pyrlimnometer in two plates, or filter-carriers, as follows:

Plate I	*Plate III*
RG–5	RG–1
RG–2	GG–11
RG–1	GG–7
OG–2	GG–5
OG–1	GG–3
GG–11	GG–2
GG–1	GG–1

The eighth opening of the plate was filled by an opaque disc, with which the readings of the plate began and ended. The reading from filter GG–1 represented 100 per cent of radiation and readings began at the red end of the spectrum. Filters RG–1 and GG–11 were repeated in each plate so as to connect the two parts of the series; plates were changed so that I and

III were read successively at each depth. Filter 88a was mounted in another plate; at 1 m. it gave only 4-6 scale-divisions of the 0.333 mv. range, and could not be read at greater depths.

General Conditions of Work. In addition to observations on the composition of radiation, much work was done in 1930 on transmission of radiation, similar to that done in 1929 but more detailed. This required the use of two more sets of filters, numbering 12 in all; and a full set of readings demanded much time and good sunshine.

Such a set of readings in a fairly transparent lake, employing all of the filters at all necessary depths, calls for over 200 readings of the pyrlimnometer and requires two hours or more even under the most favorable conditions. Thus in Black Oak Lake, part of whose record is discussed in some detail on p. 404, plates I and III were read at 1,3,5, and 7 m., and plate I at 9 m., requiring 105 readings and 46 minutes, 9.00 to 9.46 a. m. Plate II was read at 0.5, 1,3,5,7, and 9 m., 65 readings and 26 minutes. At 10.18 the first small cloud touched the sun and others also followed, causing delay so that it was 11.15 when the work was completed with 44 readings of the small pyrlimnometer in the upper meter. This was unusually rapid work, up to the last set. There were no clouds or haze and the surface of the lake was smooth. In Weber Lake on August 16, 189 readings required 2 hours; in Silver Lake, August 22, 224 readings, partly involving comparison of filters, were made between 8.27 and 10.25 a. m.

During the summer of 1930 substantially no readings were made at greater depths than 10 meters, and this fact partly accounts for the rapidity of the work, since change of plates can be made quickly if depths are small. The studies both on transmission and on the composition of the spectrum consider only parts of the total spectrum and there is ordinarily not enough radiation in these parts to permit observation at greater depths. Even where the greater depths could be reached in the more transparent lakes, observation rarely extended below the epilimnion. If the pyrlimnometer passes into the lower and colder water some five minutes are needed to allow the thermopile to assume the temperature of the colder water and we did not wish to incur this delay.

No summer is likely to be more favorable for the work with the sun than was that of 1930. Between June 27 and July 13 there was much cloud and only 5 days were available for this work. But from July 14 to August 29 there was an almost continuous series of days with sunshine. In this period of 47 days 36 were used and 3 more might have been. Very few of these days yielded sunshine throughout the day. Clouds began to reach the sun not long after 10 a. m. and often became so dense as to stop work by 11 o'clock. Such clouds were likely to continue until after 3 p. m. As a result, it was necessary to utilize the earlier morning hours for work, and observations ordinarily began shortly after 8 a. m.. During the summer 51 lakes were visited, many of them more than once so that 74 series of observations were made. These differed in extent both with the lake and with the behavior of the sun. Altogether there were made about 9,700 readings of the pyrlimnometers. In this work Mr. Birge handled the pyrlimnometer and Mr. H. C. Baum read and recorded the millivoltmeters.

2. The Percentile Cumulative Curves

The scale readings of the millivoltmeter, obtained at any depth from this series of filters, indicate the amount of radiation delivered by that part of the spectrum which lies between about 7,500 Å and the cut-off of the successive filters. These may be computed as percentages of the total radiation—that derived from the scale-reading of GG–1—and platted as a percentile cumulative curve beginning at 7500 Å and reaching 100 per cent at 3500 Å. Before discussing these curves their relation will be shown to curves of solar radiation in water, but obtained in a different way.

Fig. 3 shows the envelope of a normal solar energy curve, (E—E) constructed for air-mass 1.5 and for 0.5 cm. of precipitable atmospheric water. The ordinates for this curve were furnished to us in 1916 by Mr. F. E. Fowle of the Smithsonian Institution, whose assistance has been of the greatest value to us. Within this curve is platted the corresponding energy curve (W—W) which would be found at a depth of 100 cm. in distilled water, mainly according to the results of Aschkinass ('95). This curve represents about 47 per cent of the radiation in the total curve, correction being made for the large

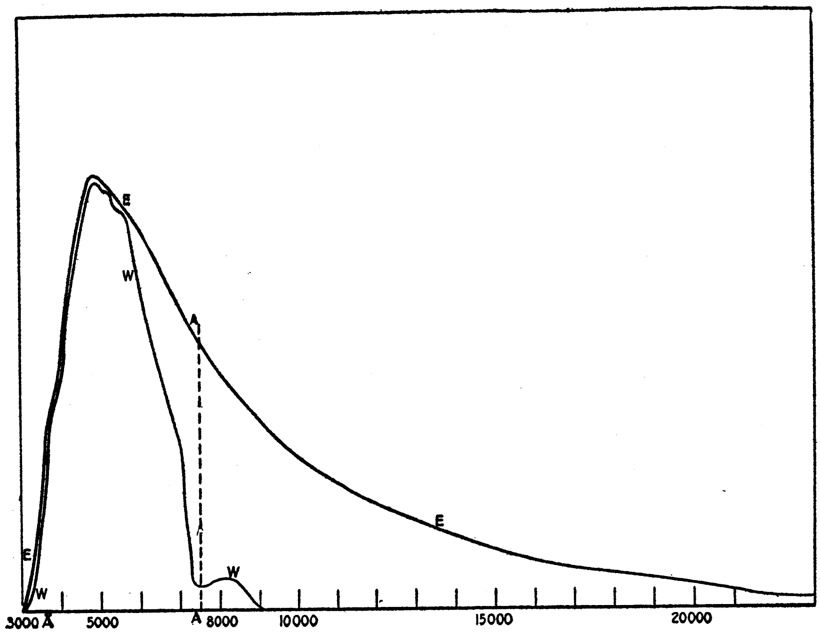

FIG. 3. Envelope of normal solar energy curve (E—E) computed for air mass 1.5; precipitable atmospheric water, 0.5 cm. The corresponding energy curve (W—W) for a depth of 1 m. in distilled water, mainly according to data from Aschkinass, '95. The position of the A line is shown.

absorption bands in the infra-red, but not for reflection from the surface. It will be noted that substantially all infra-red radiation is removed by 1 m. of distilled water.

In order to present this situation in more convenient form, part of the spectrum—from 3000 Å to 8000 Å—is platted in fig. 4 on a scale which keeps the ordinates unchanged but makes the abscissas four times as great. Within the envelope (E—E), are platted the corresponding curve for distilled water at depth of 1 m. and also three similar curves for the filtered water of three lakes, Mendota, Trout, and Turtle. These are derived from the paper of Pietenpol ('18) and the ordinates for these curves are found by converting the coefficient of extinction stated by Pietenpol into per cent of transmission. The readings of Pietenpol were limited by the range of the spectrophotometer, but they were extended in these cases by the aid of the bolometer both to shorter (4000 Å) and to longer wave-lengths. The area included in any one of these curves is measured by a planimeter and made equal to 100 per cent; the areas are measured which are included in the parts of the curve, beginning at 8000 Å and ending at the successive lines indicating intervals of 500 Å. From these areas, computed as percentages of the total area, is built up a percentile cumulative curve, beginning at the red end of the spectrum.

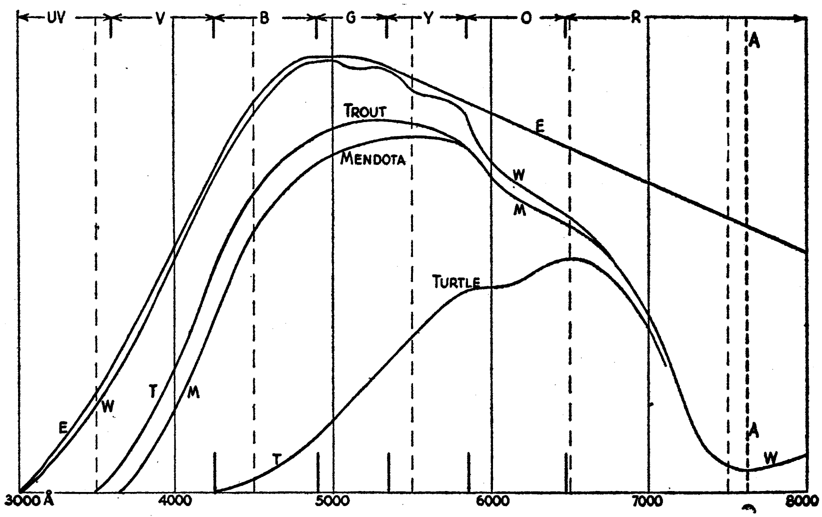

FIG. 4. Part of the curve of fig. 3 (3000 Å—8000 Å) platted with the same ordinates and with abscissas four times as great. E—E envelope, W—W, distilled water, as in fig. 3. Similar curves for filtered water of Trout, Mendota, and Turtle lakes, from the observations of Pietenpol '18. Color of distilled water on platinum-cobalt scale, 0; Trout Lake, 6; Lake Mendota, 8; Turtle Lake, 93. For discussion see pp. 395–397.

The results of thus transforming the areas of fig. 4 into cumulative curves is given in fig. 5, which shows the quantitative distribution of radiation in the spectrum and also the effect on this distribution which is due to the presence of stain in the water. Many quantitative conclusions may be drawn from these curves when they are platted on coordinate paper. Fig. 6 shows certain of these results. This diagram like figs. 10 and 14, shows four main items, three of which come from the cumulative curves.

1. The quantity of radiation present at the depth indicated is shown by the narrow bars marked T. It is stated as a percent-

age of the radiation delivered to the surface of the water. In the case of distilled water this is 47 per cent, and if the amount at the surface of the lake is estimated as 1.5 cal/cm²/min. the value at 1 m. is 0.7 cal/cm²/min.

FILTERED WATER

	Color	% at 1 M.
Distilled	0	47
Mendota	8	34
Turtle	93	13

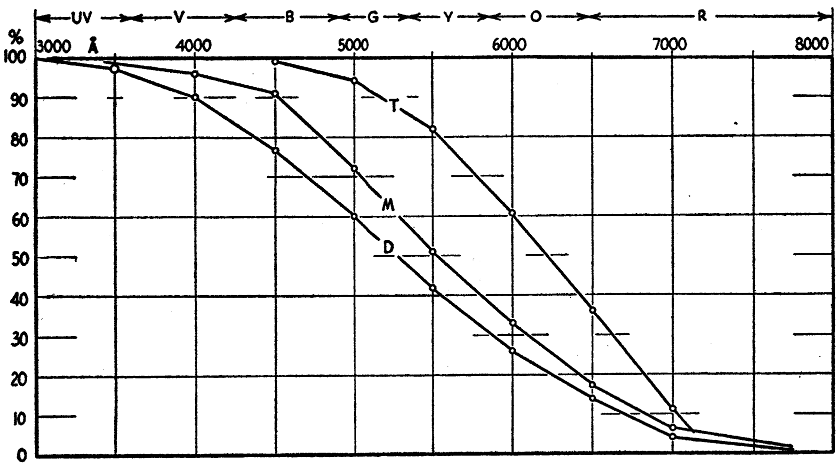

FIG. 5. Percentile cumulative energy curves derived by measurement from fig. 4. See p. 394. D, distilled water; M, Lake Mendota; T, Turtle Lake. These are to be compared with similar cumulative curves derived from lakes by the use of light-filters and shown in fig. 9.

2. This item and the following two relate to the composition of radiation at the depth of 1 m. The percentile distribution is shown by the broad bars, which are partly shaded. Total radiation is placed as 100 per cent and is divided by wave length into five parts, each corresponding to 1000 Å or sometimes in the end sections to 500 Å. The divisions corresponding to 3000-4000 Å, 5000-6000 Å, and 7000-8000 Å are shaded; intermediate divisions are left open. By tracing the relative size of these divisions through the series, the effect of stain on the distribution of radiation in the spectrum can be readily seen.

3. The circular diagram at the head of each broad bar shows by its sectors the distribution of radiation to the several colors of the spectrum. In these diagrams no separate ac-

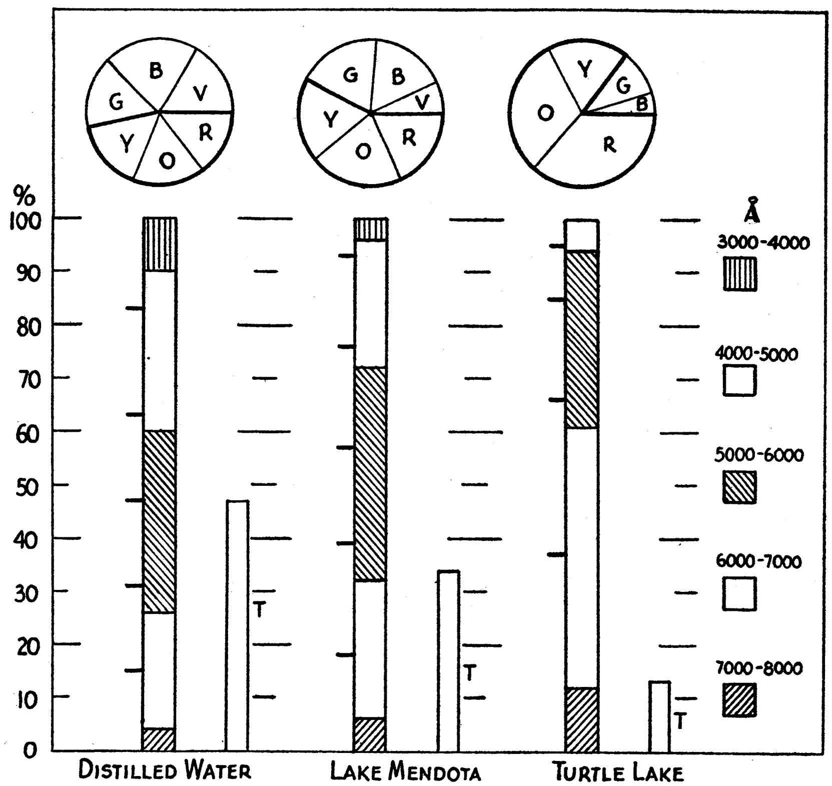

FIG. 6. Distribution of radiation in the cumulative curves of fig. 5. The shorter and narrower bars marked T, show the total amount of radiation present at 1 m. as a percentage of that incident on the surface. Broader bars show percentile distribution of radiation by wave-lengths. The spectrum is divided into 5 regions each covering 1000Å. In these note percentile decrease in the short-wave regions and corresponding increase of the others, as color of water rises. Circular diagrams show distribution of radiation to the several colors, see p. 398. Note in the series the decrease in the size of sectors belonging to the short-wave colors, and the increase of long-wave sectors, especially red. On the left side of each percentile bar are short lines indicating percentages of the colors shown by sectors in circular diagrams above. Fig. 6 is to be compared with fig. 10.

count is made of any small amount of ultra-violet or infra-red which may be present at the depth of 1 m. The limits of the several colors are taken from Landolt and Börnstein ('23. p.806) as follows:

Limits of Colors, Wave-Lengths.

Color	*Wave-Length*
Violet	3600–4240 Å
Blue	4240–4900
Green	4900–5350
Yellow	5350–5860
Orange	5860–6470
Red	6470–8000

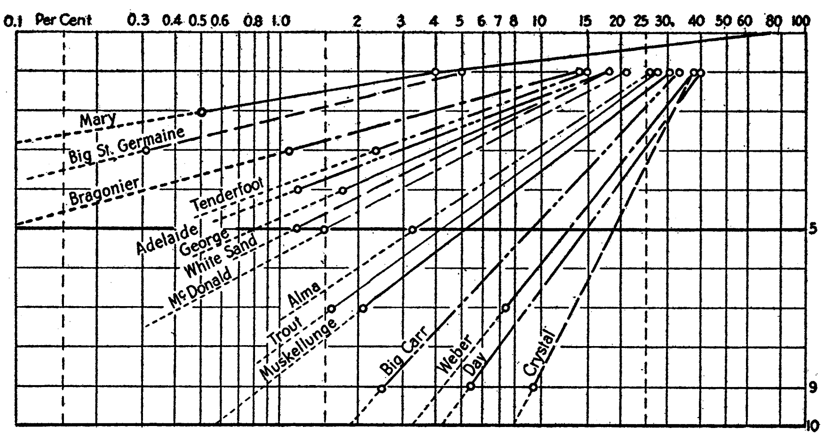

FIG. 7. Data from a series of lakes, showing the per cent of incident radiation present at 1 m. and the average transmission of radiation below that depth. This figure is to be compared with similar figures in earlier papers. See Birge and Juday, '30:303.

Each circle is divided into sectors corresponding to the percentage of the total radiation found within the limits thus stated and each sector is lettered with the initial of its color. The diagrams of fig. 6 show the effect of color in lake water on this distribution.

4. The percentages corresponding to the several sectors of the circular diagram are indicated by short lines on the left side of the bars that show distribution by wave-lengths.

The diagrams exhibit in a more direct quantitative fashion the facts shown by the cumulative curves. For instance, under the conditions assumed for the filtered waters, just 40 per cent of the radiation present at the depth of 1 m. in distilled water comes from wave-lengths shorter than 5000 Å; in filtered water from Lake Mendota 28 per cent comes from the same region of the spectrum, and only 6 per cent in water from Turtle Lake. The region 6000-7000 Å furnished 22 per cent of the radiation in distilled water and 49 per cent of the much smaller amount present in the highly colored water from Turtle Lake.

The circular diagrams show the distribution of radiation to the several colors and the effect of the stain present in water. For example, red, orange, and yellow—the three long-wave colors—contribute less than one-half of the radiation in distilled water; the marks on the side of the corresponding bar show that the percentage is 47. In the case of the water from Turtle Lake the same colors contribute nearly seven-eighths of the total radiation, or more exactly 85 per cent. The effect of color on the absorption of short-wave colors by 1 m. of filtered water can be traced in the series of diagrams, as well as its effect on the percentile increase of the others, especially of red.

Readings in lakes with the series of light-filters furnished data not unlike those derived by measurement from such curves as those of fig. 4. Each filter transmits substantially all of the radiation contained in wave-lengths greater than those at the position of its cut-off (fig. 8). Since infra-red radiation is

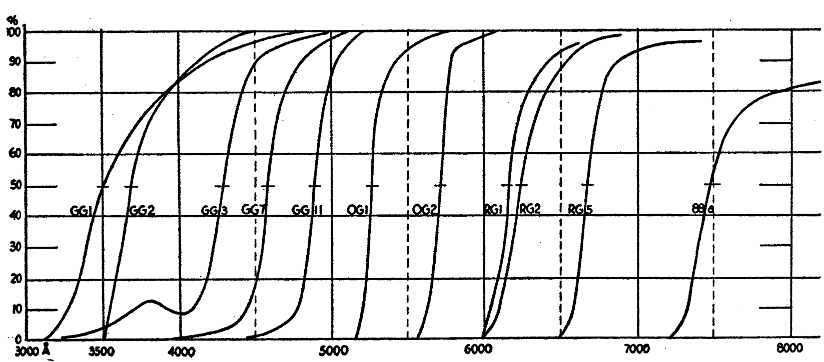

FIG. 8. The "cut-off" of the several filters used in these observations. This diagram combines results shown separately for each filter in the catalogue of the Jenaer Glaswerk. Each filter transmits all radiation from the region of the spectrum which lies to the right of the line representing the filter; except that some of the filters are opaque to that per cent of the radiation indicated by the space between the upper end of th filter line and that indicating 100 per cent. In the cumulative curves the results of observation are platted as a per cent of the total at the wave-length where the line of the cut-off intersects that representing 50 per cent of the radiation. Note that filter 88a is a Wratten filter, the others are of Jena glass, 2 mm. thick.

eliminated by beginning the readings at the depth of 1 m., the reading of the pyrlimnometer derived from any filter is that furnished from that part of the spectrum between the cut-off of the filter and 7500-8000 Å. Thus the series of readings yields a percentile cumulative curve essentially similar to one of those given in fig. 6. Such curves, derived from field observations in lakes, cannot furnish results as accurate as can be obtained from observations on filtered water in a laboratory. The fact that the cut-off of any filter cannot come at a single wave-length, but must occupy a spectral band of considerable width, operates against accuracy in platting. But a comparison of

LAKE	COLOR	TRP.M.	%1M.	TRM.%
CRYSTAL	0	12.0	38	84
BIG CARR	9	5.1	34	72
McDONALD	17	5.1	24	52
ADELAIDE	34	3.2	18	40
FOUND	37	1.2	10	34
HELEN	97	1.3	5	15
MARY	123	1.7	4	13

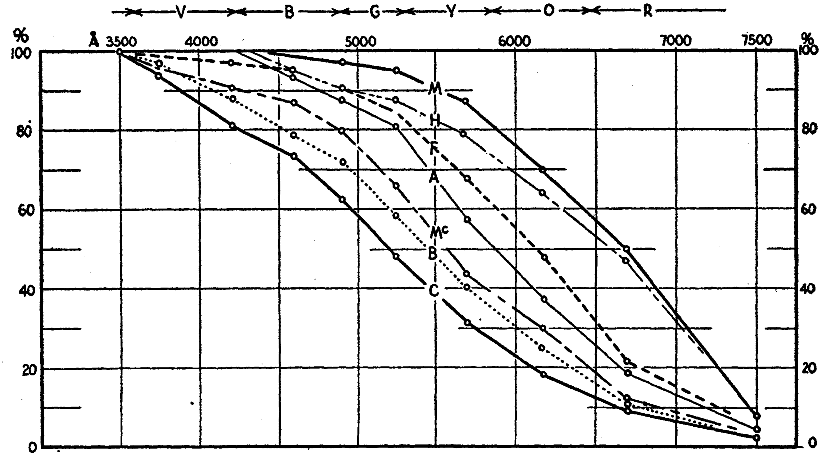

FIG. 9. Percentile cumulative curves of radiation at 1 m. in a series of lakes, from those whose water has least color (Crystal) to those most deeply stained (Mary). Note change of form of curves as color rises; difference in short-wave region between Adelaide and Found, whose color is much the same. Note general regularity of curves together with individual irregularities, such as the apparently low reading at 4250 Å in Crystal, in Helen at 4900 Å, etc.

5500 Å may be taken without serious error as representing the middle of the spectrum. Note that in Crystal Lake 60 per cent of the radiation comes from wave-lengths shorter than this, and only 10 per cent in Mary, the series showing the progressive elimination of short-wave radiation as color increases. This figure is to be compared with fig. 5.

fig. 5 and fig. 9 shows that the results reached by the two dissimilar methods are in satisfactory agreement and that the field observations disclose the essential facts.

In discussing results the terms "short-wave" and "long-wave" radiation are used in a comparative sense, within the limits of the spectrum as found at 1 m. in water; they do not connote any exactly limited regions of the spectrum. In general, short-wave means radiation with wave-lengths of 5000 Å or less. Short-wave colors are violet, blue, and green; long-wave colors are yellow, orange, and red. The region 5000-6000 Å may be called the middle region of the spectrum; and green and yellow are the middle colors.

3. Distrubution of Radiation in the Spectrum of Lakes at the Depth of One Meter

Fig. 9 gives a general picture of the composition of radiation in lakes at the depth of 1 m.; the series extends from those lakes with the most transparent water to those whose water is very highly colored. It includes also lakes with relatively little suspended matter (Adelaide) and those with much (Found). Detailed data for these and for all of the 43 lakes are given in table II at the end of this paper.

The reading of each filter in the series is computed as a percentage of that from the total radiation and is platted at its proper place in the spectrum (p. 389). These points are connected by straight lines, no attempt being made to fit a smooth curve to the data. Thus all irregularities in the observations are fully brought out, and they remain in the diagrams and also in the tables derived from them. Any observer of the cumulative curves will note points which seem to be too high or too low in comparison to adjacent readings; but the number of lakes observed is still so small that it is inadvisable to try to correct curves which, like these, give good approximate results without correction.

The curves shown in fig. 9 have a close general resemblance to those of fig. 5, showing a good agreement between the results of observation with light-filters and with the spectrophotometer or bolometer. There is the same general form of curve and the same difference between curves from the transparent waters and from those which are colored. Fig. 12-17 give similar cumulative curves for five other lakes and fig. 19-20 show distribution by colors in 12 additional lakes.

From fig. 9 many conclusions may be drawn regarding the quantitative distribution of radiation in the spectrum of lakes at the depth of one meter. Certain of these conclusions are shown in fig. 10 which has the same relation to fig. 9 that fig. 6 has to fig. 5.

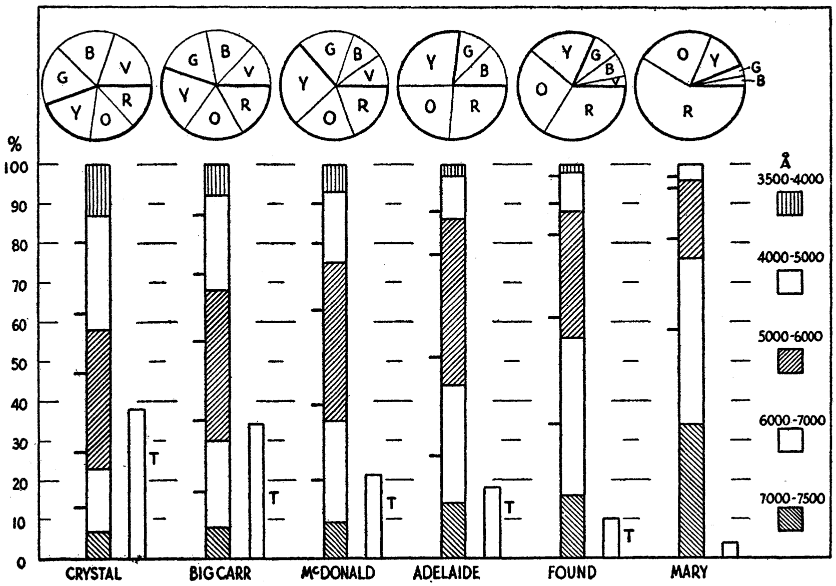

FIG. 10. This figure is to be compared with fig. 6 and its explanation. It shows the quantity of radiation present in these lakes and its distribution both by color and by wave-length. Note in the series of diagrams the increase in percentage of long-wave radiation with increasing color; also the progressive lengthening (or shortening) of the several 1000 Å intervals. In circular diagrams note increase of sectors coming from long-wave colors and especially increase of red.

The shorter and narrower bars marked T show the total amount of radiation present at 1 m. in these lakes, stated as a percentage of that delivered to the surface of the lake. Computation is made as stated in Birge and Juday '30:289. In Crystal lake this amount was 38 per cent, while at the other end of the series Lake Mary had only 4 per cent or about one-tenth as much. Lake Helen (color, 97) for which there is no diagram in fig 10 had 4.6 per cent. In the case of the filtered water, Turtle lake with a color of 93 had at 1 m. about 13 per cent of the radiation delivered to the surface, or a little more than one-fourth of that present in distilled water. This difference between the filtered waters and those of the lakes is mostly due to the differences in suspended matters; but it is by no means improbable that part is due to the presence of stains of different character in the waters of different lakes. Our knowledge is as yet insufficient for discussion of these details.

The broad shaded bars in fig. 10 show the distribution of radiation to the several wave-length intervals and comparison of these will show the many changes in this distribution which come with increasing color in the water. For instance, in Crystal Lake 42 per cent of the total radiation comes from wave-lengths shorter than 5000 Å; in Adelaide Lake 14 per cent comes from the same region and in Lake Mary 4 per cent. The amount derived from wave-lengths greater than 7000 Å rises from 7 per cent in Crystal lake to 34 per cent in Lake Mary. Similar changes may be seen in every region if it is traced through the series.

The circular diagrams of fig. 10 show the distribution of radiation to six colors of the spectrum in these lakes, and those in figs. 19 and 20 give similar diagrams for 12 additional lakes. These are to be compared with the like diagrams given for filtered waters in fig. 6. In Crystal Lake, as in the distilled water, the sectors for the several colors are not widely different in size; percentile figures are given in table II. As the color of the water rises the differences increase between the sectors assigned to the several colors. Those for violet and blue decrease and violet finally disappears; green follows blue in declining; the sectors for the three long-wave colors increase; yellow and orange rising more than red in lakes with moderate color; while red predominates in the radiation left in lakes with the most deeply stained water. In Lake Mary red included 58 per cent of the small amount of radiation left at 1 m., while in Crystal Lake the same color contained only 14 per cent of the total. It should be noted that the 58 per cent present in Lake Mary represents about one-third of the energy yielded by the 14 per cent of Crystal Lake.

The longer series of lakes in figs. 19 and 20 shows the same characters, if the diagrams for 1 m. are compared. They show also that there is a variation of details from lake to lake for which we cannot account at present. For instance, the sectors in the diagrams for 1 m. for Edith Lake and White Sand Lake are more alike than would be expected from the difference in color. Kawaguesaga and Midge lakes are less alike; some violet would be expected in Lake Adelaide as in Lake George; and detailed examination of the diagrams will show other matters of like import. Some of these may be due to instrumental errors, but most of them probably come from differences in the transparency and color of the lakes and their waters.

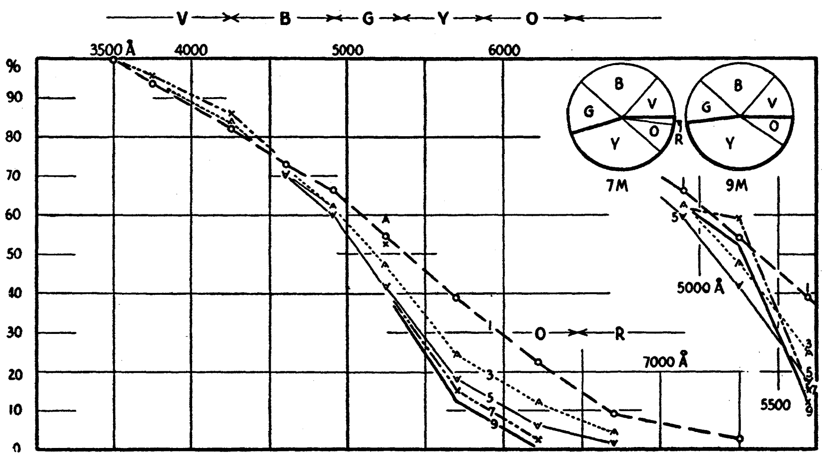

FIG. 11. Crystal Lake, August 17. Transparency, 12.0 m.; per cent at 1 m., 38; transmission, 84; color, 0. All curves very close together in region to left of 5000 Å, so that accidental variations determine relative place. The 7 m. curve shows beginning of increased loss in this region but percentile loss is not increased at 9 m. Readings for 5250 Å at 7 m. and 9 m. showed a change of color whose results are platted on right of diagram. These readings are omitted in main curves. Curve for 1 m. is taken from a different set from that used in fig. 9 in order to show the kind of variation which may be expected in such a lake. See p. 408.

4. Changes in Distribution of Radiation With Increasing Depth of Water

In most of the lakes the spectrum was examined at depths greater than 1 m.; in the more transparent lakes the regular order was to take readings at 1, 3, and 5 m., extending to 7 and

9 m. if transparency permitted and if the thermocline lay below those depths. In waters with more stain the readings were at 1, 2, and 3 m. and in the most highly colored waters the amount of radiation left at 2 m. was too small to permit of accurate distribution. In Lake Mary for instance, the reading for total radiation at 1 m. was 40 divisions of the scale; at 2 m. the total was only four divisions, too small for distribution, as is explained in connection with fig. 18. Black Oak Lake (figs. 13, 14) offered one of the most uniform series and from a lake with fair transparency but showing unmistakable influence of the presence of stain in the water; it has therefore been selected for more detailed analysis.

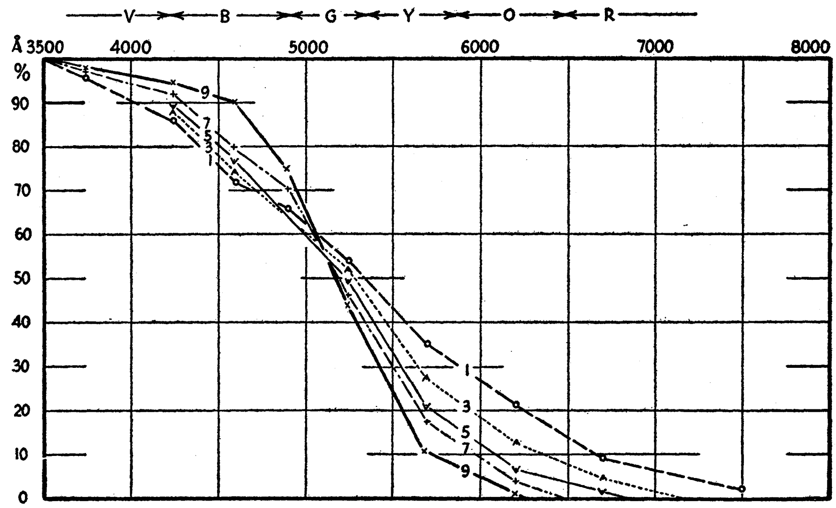

FIG. 12. Day Lake, August 29. Transparency, 9.0 m.; per cent at 1 m., 40; transmission, 78; color, 0, but curves indicate that some was present. Absorption in short-wave region increases steadily as depth increases. The lake forms a transition from the most transparent, like Crystal, to those with small but definite color.

Black Oak Lake was observed under exceptionally favorable conditions of sun and wind, and the results are correspondingly regular. They are almost exactly similar to those from Big Carr Lake (fig. 9), which is about thirty miles distant. The agreement at 1 m. is so close that both lakes cannot be platted on the same diagram without confusion (see table II) and an equally close resemblance is found at all depths.

Black Oak Lake has a small but definite amount of stain in its water. The result of this condition is that the percentage of radiation furnished by the two ends of the spectrum falls off as depth increases. Radiation from the long-wave part of the spectrum falls off, due largely to the effects of water as water; there is a similar decline in the percentage from the short waves, due primarily to the effect of stain in the water. It follows that as the percentile contribution from the ends of the spectrum decreases that from the middle of the spectrum increases with greater depth.

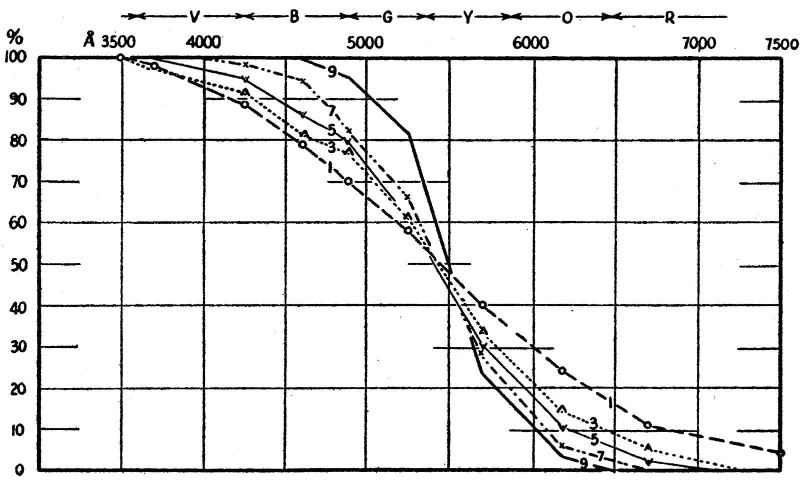

FIG. 13. Black Oak Lake, Aug. 21. Transparency 5.8 m.; per cent at 1 m., 34; transmission 69; color, 10. These curves show the kind of regularity and variation which may be expected under the best conditions of sun and wind in a lake whose water is of the oligotrophic type. Note difference of absorption in short-wave region of this lake and in those with less or with more stain in the water. Note that the place of intersection of the curves is at a longer wave length than in more transparent waters, and that it also comes at a lower per cent of the total radiation. In this case about 50 per cent of the radiation comes from wave-lengths shorter than this point, as compared with about 60 in Crystal and Day lakes. Note the marked difference between short-wave radiation in curves for 7 m. and 9 m., seen also in Day Lake.

Thus there is a characteristic appearance in a series of cumulative curves from different depths in the lake whose water is not too deeply stained. Fig. 13 shows that in Black Oak Lake these curves tend to cross each other at a rather definitely marked region, about 5400-5500 Å. It does no violence to the appearance of the diagram to say that these percentile curves seem to be moving in a clock-wise direction about this center so that an increasingly great percentage is being thrown into the region between 5000 Å and 6000 Å. It is plain that at greater depths (if color remains the same) practically all remaining radiation will be found in that region and, indeed, restricted to the center of it.

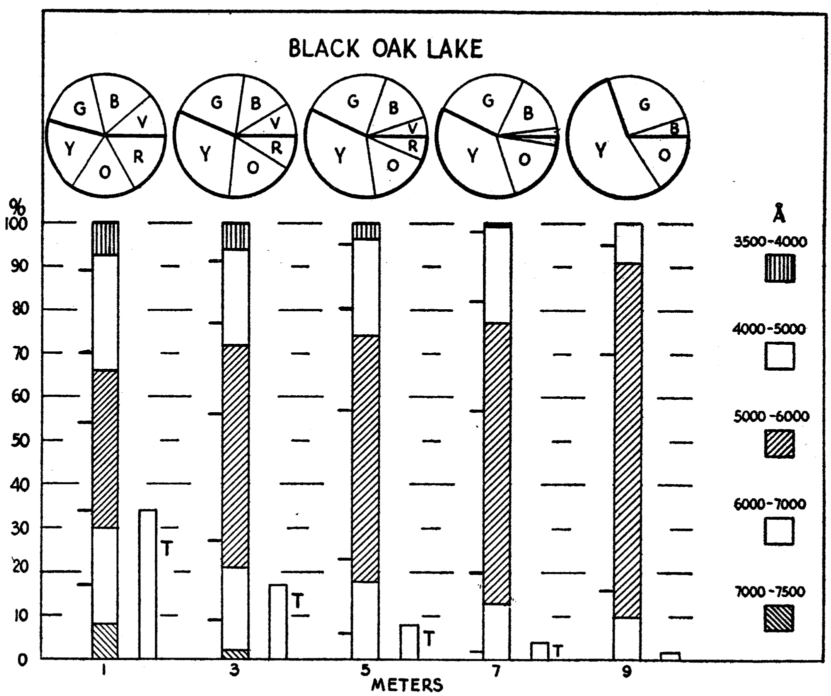

FIG. 14. Distribution of radiation in Black Oak Lake. To be compared with figs. 6 and 10. See explanation of fig. 6. In the percentile bar diagrams note decrease and ultimate disappearance of radiation from both ends of the spectrum, and rapid increase of that from 5000-6000 Å. This region yielded 36 per cent of radiation present at 1 m. and 81 of that at 9 m. In color diagrams the sectors for violet and red finally disappear; the per cent of blue declines; orange remains with little change; green increases between 1 and 3 m. but adds very little below; yellow rises greatly, increasing from 20 per cent at 1 m. to 54 per cent at 9 m. This distribution of radiation belongs to lakes with color of water from 9 to 12 as shown in table II.

The same facts are presented by fig. 14 in a way which more clearly shows their quantitative relation. As in other similar diagrams, the shorter and narrower bars marked T show the quantity of radiation at each depth as a percentage of that delivered to the surface of the lake. This decreases from 34 per cent at 1 m to about 1.5 per cent at 9 m. The maximum scale reading at 1 m. was 336 divisions (56, on the 2 mv. range) and that at 9 m. was 14, neither reading being corrected for cosine of angle of refraction of the sun's rays. With this situation the pyrlimnometer could have followed total radiation to perhaps 13 m. but its distribution could not have been determined much below 9 m. with enough accuracy to give value to the result.

The wider bars of fig. 14 show the distribution of this radiation to the several regions of the spectrum. The most striking fact is the great rise of the percentage belonging to the region between 5000 Å and 6000 Å; it rises from 36 per cent at 1 m. to 81 percent at 9 m. It is the beneficiary of the percentile decrease of the regions at both ends of the spectrum.

The distribution of the radiation to the several colors is shown in the circular diagrams. At 1 m. the sectors are not very unequal, though that for violet is definitely the smallest (see also table III); as depth increases there is a rapid shrinking of the size of the sectors representing colors at both ends of the spectrum; and there is a corresponding increase of the sectors representing central colors of the spectrum. This is most manifest in yellow, and to a much less degree in green also. At 9 m. yellow, which contained less than 20 per cent of radiation at 1 m., includes more than 50 per cent. Plainly at a little greater depth practically all remaining radiation will be restricted to this sector of the spectrum.

Such a series of diagrams should be compared with the series in fig. 10. Those show the effects of increasing color of the water on composition of radiation at the same depth in different lakes; while fig. 14 shows the effects of a constant color on radiation at different depths in the same lake. In the first series increasing color threw the greater part of the radiation into the red sector of the diagrams; in this case a moderate color throws the greater part into the sector for yellow. In all series of the sort that sector will increase most rapidly which lies nearest the point in the spectrum where the cumulative curves cross, as shown in fig. 13.

These diagrams of Black Oak Lake are substantially like those which would come from those lakes whose water has about the same amount of color as Black Oak—the 12 lakes in table II from Big Carr to Little Tomahawk. Round Lake furnishes a transition to the lakes with more transparent water, and the lakes with colors of 12 look toward those with color of 16. But on the whole these lakes constitute a group with similar characters.

The other diagrams representing percentile cumulative curves for depth show the conditions in lakes of other types. Figs. 11 and 12 show lakes whose water has less color than Black Oak, and figs. 15-18 those with more color. The water of Crystal Lake (fig. 11) has the lowest color found in northeastern Wisconsin, though its transmission of radiation is not quite so great as that of Day or of Diamond lakes. That part of the curves of fig. 11 which lies to the right of the point indicating 5700 Å is much like the corresponding part in fig. 13, but the part from 3500 Å to 5000 Å is quite different. In this region most of the curves are close together and small variations of sun or lake determine their relative position. Only when 7 m. is reached is there an obvious decline in the percentage found at 4250 Å; 9 m. shows the same decline but not in a greater degree. All four curves from 3 m. to 9 m. come together at about 4900 Å where they lie at 60-62 per cent; but there is no definite crossing at this point as there is at 5500Å in Black Oak Lake.

This situation in Crystal Lake is not unlike that which results in distilled water if the computations used for the curve in fig. 5 are carried to greater depths. These would show a simiiliar convergence in the spectrum but at a point about 4500 Å, where there would be found between 75 and 80 per cent of the total.

This series in Crystal Lake presented an individual peculiarity which is shown in the diagrams at the right side of fig. 11. The readings of the filter OG-1 (5250 Å) at 7 m. and 9 m. showed a marked change from those at smaller depths and from those given by adjacent filters. They indicated a percentage at this point in the spectrum that was much larger than was found at smaller depths; but the readings of the next filter in the series, GG-11, were exactly in line with those at the less depths. If only a single reading had been concerned, it would have been considered an accidental error; but this explanation does not seem plausible when a second similar reading was taken two meters deeper and after a five minute interval. Both readings were near the thermocline and possibly in water with more stain than was present at higher levels. The effect of the reading is to throw the increase of per cent at these depths into yellow rather than green and this is shown by the sectors of the two circular diagrams placed in fig. 11. The readings are disregarded in the main curves and in the diagrams of this lake in fig. 19.

Curves for Day Lake are given in fig. 12. This lake was recorded as having no color on the platinum-cobalt scale, but the curves show that there must have been a slight amount. The lowest color disc furnished with the apparatus for determining color on this scale has a reading of 8, and lower read-

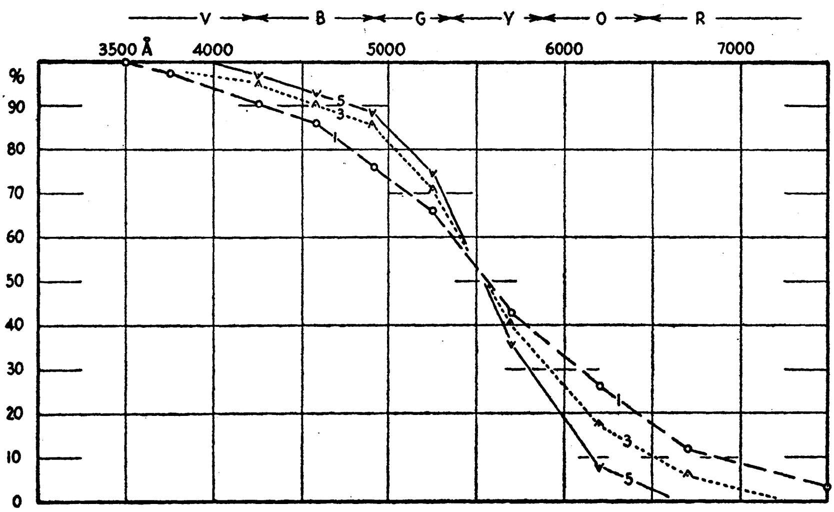

FIG. 15. Kawaguesaga Lake, July 21. Transparency, 3.9 m.; per cent at 1 m., 26; transmission, 58; color, 16. This lake is taken to represent those with color of water ranging from 16 to 20, in which radiation was followed only to depth of 5 m. Note that only 27 per cent of radiation at 1 m. comes from short wave part of spectrum, as compared with 34 per cent in Black Oak Lake. At 5 m. this region furnishes 15 per cent, as compared with 26 per cent in Black Oak.

ings must be estimated. The diagram shows a condition intermediate between Crystal and Black Oak lakes. Percentages in the long-wave part of the spectrum, from 5250 Å, are much the same as in Crystal Lake and lower than in Black Oak Lake. All curves come close together near 5000 Å but they do not continue together beyond this point as they do in Crystal Lake; they cross and thus resemble those of Black Oak Lake, though on a higher scale of transmission. Nearly 10 per cent of the total radiation at 9 m. comes from wave-lengths shorter than 4500 Å; the corresponding figure for Crystal Lake is 23 per cent; while in Black Oak Lake the 9 m. curve does not extend to 4500 Å. Note that the 1 m. curves in Crystal and Day Lakes are much alike; differences come out with increase of depth.

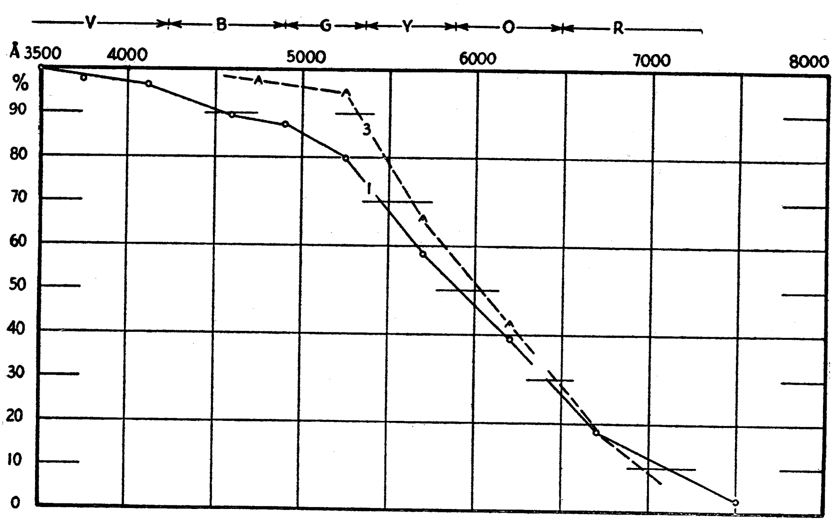

FIG. 16. Midge Lake, Aug. 23. Transparency, 4.1 m.; per cent at 1 m., 19; transmission, 46; color, 29. In this lake curves are platted for 1 and 3 m. Note small amount of short-wave radiation (15 per cent at 1 m.) and its rapid decline. Curves for 1 m. and 3 m. show the same percentage at 6700 Å; this would give a slightly larger percentage for red at 3 m. than at 1 m. (see fig. 20). Red shows a decrease with depth both in lakes whose water is less colored than that of Midge and also in lakes more highly colored. See other cases in fig. 20 and also p. 416.

Kawaguesaga Lake (fig. 15) furnished the best set of curves from the lakes whose water had a color of 16-20. Readings were made at depths of 1, 3, and 5 m. There are obvious irregularities in the curves at about 4900 Å and it seems probable that in most lakes of this type the curves would cross at a greater wave-length than is shown here. In this series the crossing lies at about 5500 Å, while in other lakes of the same type it lies at 5700 Å or even nearer to 6000 Å. The percentage in the short-wave part of the spectrum is much smaller than in Black Oak Lake. That lake at 5 m. gets about 26 per cent of the radiation from wave-lengths shorter than 5000 Å, while Kawaguesaga Lake gets only 16 per cent from the same region.

In the lakes with more highly colored water readings extended only to 3 m. and in the case of Lake Mary only to 1.5 or 2.0 m. The curves show the same peculiarities modified by increase of color, and in most cases these peculiarities are well indicated in the explanation of the several figures.

All of the lakes with water colored from 30 to 40, like Midge Lake, (fig. 16) show a like situation in the part of the curves for

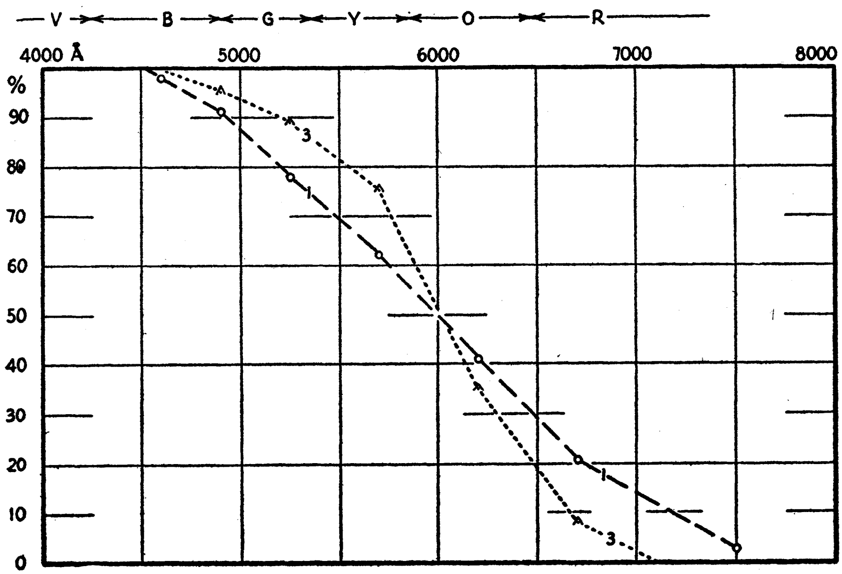

FIG. 17. Tenderfoot Lake, Aug. 26. Transparency, 3.0 m.; per cent at 1 m., 15; transmission, 40; color, 49. Here the percentage of radiation between 6000 Å and 7000 Å falls off with depth in spite of high color of water. In this respect it resembles Allequash Lake, table II. Other lakes with color of 30 and upwards show the same fact but in smaller degree. Little Papoose Lake (color, 36) shows a percentile increase in this region. See fig. 20.

wave-lengths greater than 6000 Å. There is little difference betwen 1 m. and 3 m. in the percentage found in this region. On the other hand, Tenderfoot Lake (fig. 17) shows a marked change in this region; a change far more noteworthy than that in Midge Lake. The water of Tenderfoot Lake has a color of 49 while that of Midge Lake has 34. Allequash Lake, which has a color of 49, shows the same feature as Tenderfoot; no explanation for this difference can be given by us. Reference to similar differences will be found in the explanations for figs. 19 and 20.

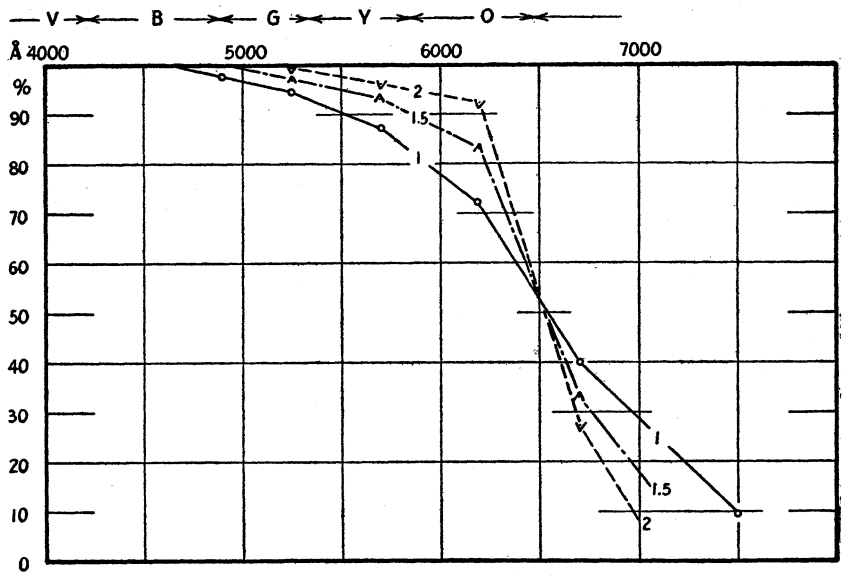

FIG. 18. Lake Mary, Aug. 18. Transparency 1.7 m.; per cent at 1 m., 4.0; transmission, 13; color, 123. Radiation in this lake was followed to 2 m. at which depth the amount present was too small for distribution and the curve for 2 m. is computed from those at 1.0 and 1.5 m. In these deeply stained waters little radiation is present from wave-lengths shorter than 5,000 Å; at 1 m. in Mary about 60 per cent comes from the 6000-7000 Å region and at 2 m. the percentage is 85.

The curves for Lake Mary (fig. 18) and for the three other lakes closely associated with it (table II) differ markedly from those of the other lakes. This is seen in the relative amount of radiation contained, at the depth of 1 m., in the intervals 5000-6000 Å and 6000-7000 Å. In Tenderfoot Lake the amounts in these intervals are nearly equal—37 and 35 per cent respectively. In Lake Mary only 19 per cent of the radiation is found

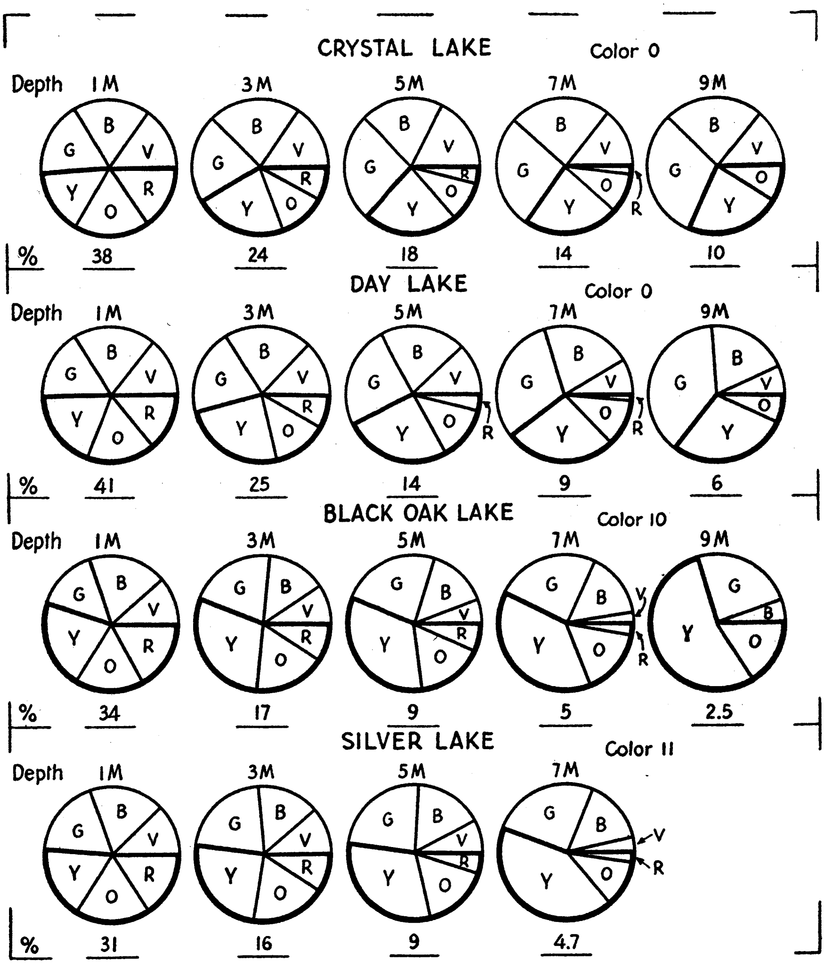

FIG. 19. The diagrams of this figure and of fig. 20 show the distribution of radiation to the several color regions in 14 lakes and the changes which radiation undergoes as depth increases. The numbers under each diagram following the sign % indicate the amount of total radiation at each depth, stated as a percentage of that delivered to the surface of the lake. These are derived from the data given in table II. Diagrams are platted from the data in table III, which should be consulted for numerical details. Diagrams from Black Oak Lake are repeated from fig. 14. Series used for Crystal and Mary lakes differ a little from those used for fig. 10.

Changes of distribution as depth increases can be followed, leading in all cases to percentile reductions at the ends of the spectrum and to corresponding increases in the middle; green getting the largest share in Crystal and Day lakes and yellow in Black Oak and Silver lakes.

in the 5000-6000 Å interval and nearly one-half—49 per cent—between 6000 Å and 7000 Å. No lakes have yet been examined whose distribution of radiation fills this gap.

5. Distribution of Radiation by Color and Depth of Water

Figs. 19 and 20 show the distribution of radiation to the several colors of the spectrum in a series of 14 lakes, selected so as to show the effect of stain in the water as depth increases. The data on which the diagrams depend are given in table III.

In fig. 19 Crystal and Day lakes are recorded as having no color in their water, though there was probably a slight amount in both lakes, greater in Day. In both lakes the sectors for the six colors at 1 m. are nearly equal and the diagrams are strikingly similar; but differences appear when the series is followed through from 1 m. to 9 m. In both lakes red disappears and orange is much reduced before the depth of 9 m. is reached. The sector for violet has decreased a little in Crystal Lake and much in Day Lake. In Crystal Lake the main percentile increase comes to the sector for green and to a less degree to that for blue; in Day Lake the sectors for green and yellow show a similar change.

If the computations for distilled water are carried to greater depths the increase will be found greatest in the blue sector, at any rate to depths of 10 m. No lake has been found with water so clear as to place the largest increase in this part of the spectrum.

Three diagrams are given for lakes with colors of 9, 10, and 11; these are Black Oak Lake (repeated from fig. 14), Silver, and Edith lakes. In these lakes the diagrams for 1 m. are not far different from those for the two more transparent lakes, though in each case the sector for violet is decidedly smaller and the combined sectors for the long-wave colors—red, orange, and yellow—occupy more than one-half of the diagram. In all of these lakes the transmission of radiation is smaller than in the first two; both ends of the spectrum are rapidly absorbed as depth increases; and the middle of the spectrum secures most of the radiation. In all of these lakes the sector for yellow would occupy more than one-half of the diagram at 10 m.; green may show a slight increase; blue shows no marked increase or decrease; orange declines; but does not disappear at the lowest depth reached.

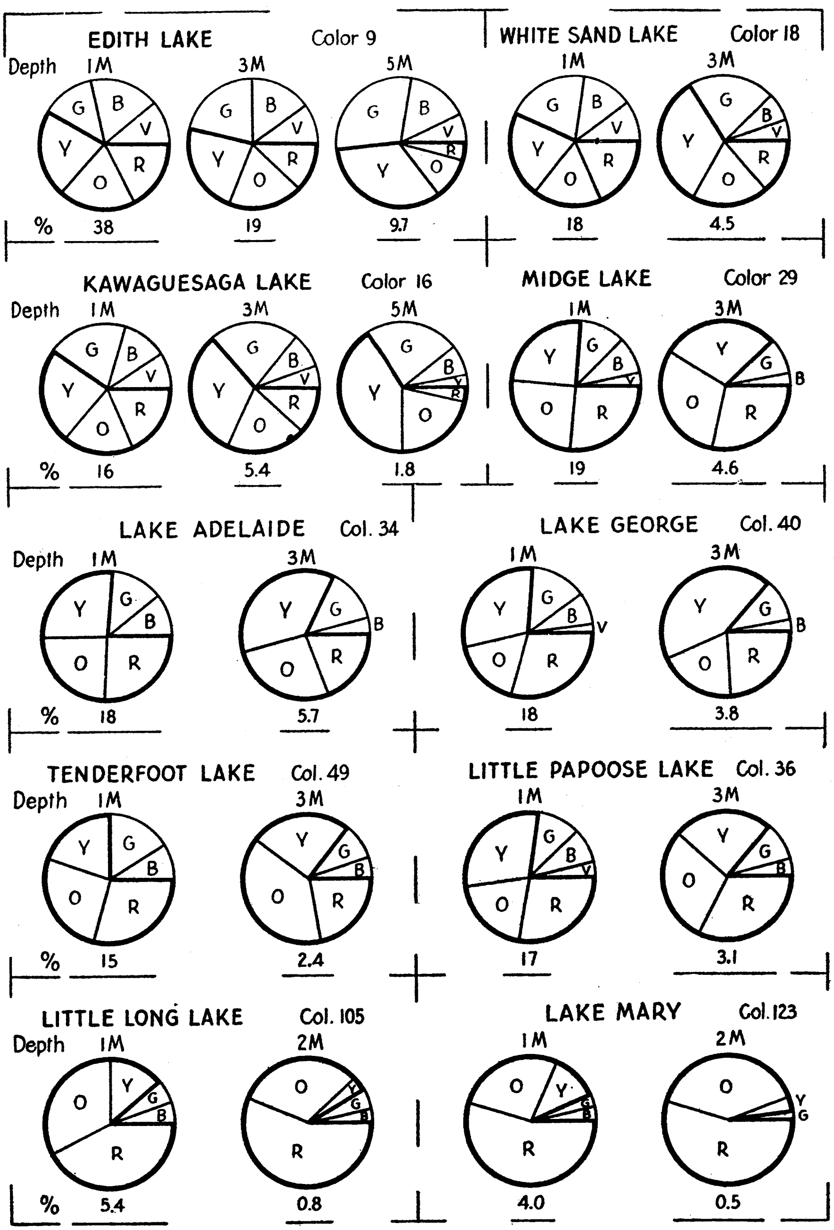

FIG. 20. Edith Lake belongs near Black Oak, between that and Day Lake, since in it the sector for yellow shows a smaller proportional increase than in Black Oak. It is inserted here to facilitate comparison with lakes whose water is more highly colored. In both Edith and Kawa-

guesaga lakes the sector for red behaves in much the same way, but blue and violet fall off more rapidly in Kawaguesaga and there is a great difference in the orange. Note also that the per cent of total found in Kawaguesaga at 1 m. is much smaller than in Edith and the general transmission is also less.

The six lakes of the series from White Sand to Tenderfoot and Little Papoose do not differ widely in the percentage present at 1 m. or in the transmission, though the color rises from 18 to 49. The distribution of the radiation however differs as does also the change with depth. In White Sand, the lake with the lowest color, the three long-wave colors, red, orange, and yellow, comprise 57 per cent of the total radiation; in Tenderfoot they include 75 per cent; at 3 m. the percentage has risen to 66 and 86 respectively. Note the behavior of the sector for red in these lakes; the per cent at 1 m. increases with color and the decline with depth is less as color increases. In Midge and Little Papoose the sector for red is greater at 3 m. than at 1 m.

Two lakes are shown from those with high colored water. In Little Long the long-wave colors include 89 per cent of the little radiation left at 1 m. Red yields nearly half of the total in Little Long and more than half in Mary. Violet is absent in both lakes. Red has a larger sector at 2 m. in Little Long than at 1 m., and its size remains the same in Mary. There is a considerable gap in this series of lakes between Tenderfoot and Little Long; which remains to be filled by later studies.

White Sand and Kawaguesaga lakes (fig. 20) represent waters with colors between 15 and 20. The distribution of the radiation at 1 m. is not very different from that in Edith Lake in spite of the fact that the quantity is less than half as great. This quantitative difference depends partly on the amount of plankton. At 3 m. and still more at 5 m. there appear great differences in the distribution. In these more highly colored lakes violet and blue have diminished far more rapidly than in Edith, and orange has increased rather than declined. Red has fallen off much as in Edith. The sectors showing most enlargement are not yellow and green but yellow and orange.

Midge Lake and the next four lakes in fig. 20 are examples of lakes with color of water ranging from about 30 to 50. All show common characters and individual differences. The distribution of radiation at 1 m. is notably different from that in lakes with less color although the quantity present at that depth is about the same. The long-wave colors—red, orange, and yellow—furnish about three-fourths of the radiation present at 1 m., instead of about one-half. Red and orange supply about one-half in quantities not very unequal, and yellow's sector is about another one-fourth. The short-wave colors are correspondingly reduced, especially violet.

There are marked individual differences visible in the diagrams for 3 m. In Adelaide and George lakes the main percentile increase falls to the yellow sector, as it does in lakes with less color. In Midge and Tenderfoot lakes orange shows the most gain. In Midge and Little Papoose lakes red increases its percentage at 3 m.; while in the others red shows a smaller sector at that depth. For the present we can note these variations but are not able to discuss them. They are probably associated with differences in the mixture of colored extractives whose average is recorded as the color of the lake's water.

There is a gap in the color series between Tenderfoot Lake (color 49) and Helen (97) which still remains to be filled by observations. In these last lakes radiation is so rapidly absorbed that readings could not extend below two meters and in the case of Lake Mary the total radiation at that depth gave a movement of only 4 divisions of the millivoltmeter — quite too small to permit distribution. In the case of Helen and Little Pickerel lakes the condition of the sun did not allow accurate work below one meter. In all of these lakes the situation at 1 m. is quite similar (table II). The quantity of radiation is very small; red furnishes nearly or quite one-half of it, and orange another quarter; yellow has a sector much smaller than in lakes with less color; violet is absent and green and blue together make up less than one-eighth of the radiation. At two meters the sector for red has increased in Little Long Lake and remained stationary in Lake Mary; orange has increased in both; blue has disappeared and green and yellow are much reduced. At depths a little greater only red and orange will be left to supply the extremely small quantity of radiation which continues to penetrate the water.

STATISTICAL TABLES.

The work of the summer of 1930 was mainly addressed to a survey of many lakes rather than to securing accurate results by numerous visits to a few. Under the prevailing conditions of sun and cloud it was not often possible to visit more than one lake in a day. In most cases, therefore, the percentages given in tables II and III rest on a single series of readings at each depth; they do not represent the average of a number of readings. This fact accounts for some of the irregularities which are noticeable in these tables and in the diagrams derived from them. Some of these irregularities are mentioned in the text and others may be found in the diagrams and in the following tables. The diagrams show that such irregularities usually become more noticeable in the short-wave part of the curves. The reading of any filter gives the full value of the spectrum from the infra-red to the cut-off of the filter, and thus the readings become larger as the short-wave end of the spectrum is approached. In computing the per cent of the total radiation furnished by any filter it is necessary to assume the equality of that part of the readings which are common to GG-1 and the other filters. No correction can be made for variations due to accident or to sun or to lake; and their results, if present, are necessarily thrown into the difference between the two readings and cause inequalities in the curves. These inequalities are likely to become greater as the amount of radiation becomes greater which is assumed to be equal in comparing readings.

Some notion of the amount of accidental variation may be learned from the percentage of the total radiation given by filter GG-11. In all of the lakes visited in the latter part of the summer this filter was read twice in each series, and two percentages were obtained from it, as shown by the arrangement of the plates (p. 390). Each per cent is the ratio of the readings of filters GG-1 and GG-11 in the two plates; each ratio, therefore, depends on two variable readings and the readings of the second plate were taken some minutes after the first. The two ratios have been compared in 58 cases from 23 different lakes, in which the value of the ratio was from 60 per cent to 95 per cent of the total. The larger number of the pair came indifferently from the first or the second set of readings, and it averaged 103.2 per cent of the smaller one. In 14 cases the members of the pair were equal; in 35 more cases the larger was between 101 and 105 per cent of the smaller; 5 were from 110 to 115 per cent, and these were on days when there was haze or cirrus cloud. This result is probably a fair representation of the situation with all of the filters.

In general, in the tables and throughout this paper, no attempt is made to state fractional percentages. The accuracy of the observations does not warrant such computation. Occasionally a fraction of a very small per cent is given, but little weight should be attached to it.

Section A, table II, gives general facts regarding the lakes discussed in this paper. Lakes are arranged in order of the color of their water on the platinum-cobalt scale. Transparency (Trp.) is measured by the visibility of Secchi's disc. Per cent of radiation present at 1 m. and average transmission (Trm.) are determined as in former papers. These numbers are in good agreement with the data used in the other columns of the table; but they were determined from a series of observations in each lake, made for this special purpose. Fig. 9 shows these results for a series of the lakes.

The remaining columns of the table show the distribution of radiation in the several lakes at the depth of one meter. For practical purposes this means the composition of the light at that depth. The data are derived from cumulative percentile curves, based on readings with light-filters. Two series of facts are shown regarding the spectrum and each of these is arranged in two ways.

1. Section C shows the percentile limits of the several regions as determined by wave-length; section D shows the same facts for regions as determined by color. The numbers show the percentage of the total radiation found at the intersection of the line of the cumulative curve and the wave-length indicated at the head of the column. In section C the figures 000 Å are omitted after 3, 4, etc.; the limits for the several colors are stated on p. 397.

2. Sections E and F show the per cent of the total radiation found within each region, both as defined by wave-length and by color.

The discussions of the earlier part of this paper depend on the data given in the table; it is not expected that the reader will examine them in detail. But it is worth while to glance at certain of the series of figures, since they disclose the facts of the general situation. One of the most instructive is perhaps the series in section C, column headed 6 (6000 Å), which shows the percentage of the total radiation found at the intersection of the cumulative curve and the line indicating 6000 Å in the spectrum. This intersection lies at about 26-28 per cent in the most transparent lakes. This means that only a little more than one-fourth of the radiation present at 1 m. comes from wave-lengths greater than 6000 Å and that nearly three-fourths comes from shorter waves. As color becomes greater the per cent shown in column 6 rises steadily but rather irregularly. At colors between 15 and 20 it is above 30 per cent; it rises to 40 or more as color increases, reaching 50 per cent in Tenderfoot Lake, whose color is 49.

In the most transparent lakes less than 30 per cent of radiation found at the depth of 1 m. comes from wave-lengths greater than 6000 Å, but the amount thus delivered is greater than that derived from the greater per cent in more highly colored waters. Tenderfoot Lake has at 1 m. about 15 per cent of the incident radiation, as compared with 38-41 per cent in the most transparent lakes, as is shown in the second column of section B. These lakes would get roughly 10 per cent of that part of the total incident radiation which is furnished by wave-lengths greater than 6000 Å, while Tenderfoot Lake receives about 7.5 per cent. From wave-lengths shorter than 6000 Å Tenderfoot Lake receives at 1 m. only about a quarter as much as the transparent lakes—7.5 per cent of total incident radiation as compared with about 30 per cent in Day Lake.

In the four lakes with most deeply stained water there is a greater rise in the percentage of radiation from wave-lengths greater than 6000 Å, reaching a maximum of 78 per cent in Lake Mary.

In section D, that part of the table noting the limitations of the colors, the junction of green and yellow is marked G-Y and it shows a similar series of facts expressed in terms of color rather than of wave-length. This junction comes at 5350 Å (p. 397). In Crystal Lake this point lies at 47 per cent, showing that less than half of the radiation present at 1 m. comes from the long-wave colors, yellow, orange, and red. The numbers in this column show that this percentage rises as color in the water increases, reaching 94 per cent in Lake Mary. It should be noted that the larger percentage of Lake Mary denotes a much smaller quantity than does the 47 per cent of Crystal Lake, about one-fourth as much.

Sections E and F of the table, showing the percentages present in each wave-length or color region of the spectrum may be followed in the same way. The percentages shown in the left hand part of each section—or the short-wave part of the spectrum—show a progressive decline as they are followed through the table and those on the other side a similar rise. For those regions near the middle of the tables the change in the percentage present in any region is often much less than the change in the position of the region in the cumulative curve. For instance, yellow in Crystal Lake lies between 30 and 47 per cent of the total, so that this color contains 17 per cent of total radiation present at 1 m.; in Tenderfoot Lake yellow lies between 57 per cent and 74 per cent, again 17 per cent of the total. In case of such an equality in the percentages of radiation present in any region, the quantities there found would be related in the same proportion as are the percentages of the total incident radiation found in the lakes at the depth in question. In these cases the figures are given in section B as 38 and 15 per cent, respectively. It would be quite possible to plat any of these percentages against the color of the water in the several lakes. In all cases the results seem to approach a straight line curve; but the number of cases is small and there is a gap in the series between colors 49 and 97. A definite quantitative correlation of color and radiation must wait for more extended observations.

In table III the depths represent distance below the surface, not distance traveled by the radiation. That is, no correction has been made for cosine of angle of refraction of direct radiation. This correction has been made in computing the value of radiation at 1 m. and the average rate of transmission as given in table II and also stated in figs. 19 and 20. This was done in order to keep the figures comparable with those in earlier papers. It would have been easy to adjust the data of this table in the same way, but it was not thought advisable to make small adjustments in these data, which rest on single series of observations and not on average of several series.

TABLE I

List of Lakes Visited in 1930
Northeastern Wisconsin

Lake	Tp.	Rge.	L. km.	A. ha.	D. m.	Date	Ob. m.
Adelaide	44	V	0.74	22	21.1	VIII, 4. 18	4
Allequash	41	VII	1.6	161	8.0	VIII, 11.	3
Alma	40	VIII	0.6	10	8.1	VIII, 12.	5
Big	42	VI	3.6	429	18.5	VIII, 8.	4
Big Carr	38	VII	1.4	94	22.8	VIII, 20.	9
Big St. Germaine	40	VIII	4.2	529	13.0	VIII, 12.	2
Black Oak	43	IX	3.7	230	26.0	VIII, 21.	9
*Blue	39	VI	2.2	54	13.0	VII, 15.	6
Bragonier	40	IX	0.7	20	8.5	VII, 27.	2
*Brandy	40	VI	0.8	32	13.6	VII, 26.	4
Crystal	41	VII	0.7	32	21.0	VII, 6, 7, 31. VIII, 17	9
Day	41	VI	1.2	52	16.0	VIII, 29	9
Diamond	41	VI	1.1	48	11.5	VII, 19, 30.	7
Edith	42	VI	1.1	32	7.5	VIII, 23.	5
Finley	40	IX	0.9	63	9.0	VII, 26. VIII, 12	6
Fishtrap	42	VII	2.0	132	10.0	VIII, 25	3
Found	40	VIII	1.6	148	6.5	VIII, 12	2
George	44	V	1.4	30	21.5	VIII, 19	4
Helen	44	V	0.4	6	15.0	VIII, 3	2
High	42	VIII	3.2	308	9.5	VIII, 25	4
*Hillis	40	VI	0.3	5	9.0	VII, 15	5
Jag	42	VI	1.2	72	3.5	VII, 28	3
*Johnson	40	VI	1.4	40	12.7	VII, 26	5
Kawaguesaga	39	VI	6.8	836	17.0	VII, 23, 26	5
Little Bass	40	VI	0.4	7	13.8	VII, 15, 26	6
Little Crooked	42	VI	1.4	109	9.0	VIII, 8	3
Little John	41	VII	1.3	75	6.8	VIII,10	3
Little Long	43	V	0.8	15	18.0	VIII, 2	3
*Little Mamie	39	VIII	0.3	10	4.5	VII, 18	3
Little Papoose	43	V	0.7	13	8.5	VIII, 2	3
Little Pickerel	39	VIII	0.4	11	5.0	VII, 26. VIII, 4	2
Lit. St. Germaine	40	VIII	5.9	534	13.0	VIII, 17	3
Little Tomahawk	38	VII	1.0	54	14.6	VIII, 20	5
Mac Donald	40	IX	1.4	52	9.2	VIII, 9	4
Mary	44	V	0.13	1.2	22.0	VIII, 18	2
Mary (Papoose)	43	VI	0.6	10	14.0	VIII, 2	5
Midge	41	VI	0.3	3.4	11.8	VII, 15; VIII, 23	4
Moon	40	VIII	2.8	24	11.0	VIII, 17	5
Muskellunge	41	VII	3.3	375	20.0	VII, 24	6
Nelson	42	VI	0.5	18	15.0	VIII, 4	5
*Pauto	40	VI	0.5	10	17.0	VII, 22	5
Plum	41	VIII	6.8	440	17.5	VII, 24	5
Round	40	IX	1.0	109	9.0	VIII, 9	6
Silver	41	VI	1.5	59	18.5	VII, 21; VIII, 22	5
Spider	42	V	2.2	115	9.0	VIII, 3	3
Tenderfoot	43	VIII	2.6	261	8.5	VIII, 26	3
Trout	41	VII	7.2	1683	35.1	VI, 27. VII, 16, 20 VIII, 3.5, 22, 25	10
*Upper Gresham	41	VI	2.0	145	8.0	VII, 23	5
Weber	41	VII	0.6	16	14.1	VII, 2.6; VIII, 16, 28	7
White Sand	42	VII	2.6	216	20.5	VIII, 6	5

Note:—Lakes marked * were examined for transmission but not for composition of spectrum. Tp = township, N; Rge = range, E; L = length; A = area; D = maximum depth; Ob = depth to which observations extended.

TABLE II

Distribution of solar radiation found in lakes at depth of one meter.

A. Lakes	B. General Data				Per Cent of Total Radiation Found at Intersection of Curve with Spectral Lines Indicating									Percent of Total Radiation Found Within Regions Indicated											Lake
					C. Wave-lgth. 000Å Omitted				D. Junction of Colors					E. By Wave-lgth. 000Å Omitted					F. By Color Regions						
	Trp. m.	% at 1 m.	Trm. %	Color	4	5	6	7	V-B	B-G	G-Y	Y-O	O-R	3–4	4–5	5–6	6–7	7–8	V	B	G[1]	Y	O	R	
Crystal	12.0	38	84	0	90	64	28	6	82	63	47	30	15	10	26	36	22	6	18	19	16	17	15	15	Cr.
Day	9.0	40	78	0	91	63	27	6	86	66	50	30	15	9	28	36	21	6	14	20	16	20	15	15	D
Diamond	9.8	41	81	0	87	62	27	7	80	65	47	29	16	13	25	35	20	7	20	15	18	18	13	16	Di.
Weber	10.3	39	76	6	86	61	27	9	80	64	52	30	17	14	25	34	18	9	20	16	12	22	13	17	We.
Round	5.5	32	74	8	86	61	27	7	80	66	49	29	17	14	25	34	20	7	20	14	17	20	12	17	Rd.
Big Carr	7.0	34	72	9	93	68	31	7	88	71	54	36	17	7	25	37	24	7	12	17	17	18	19	17	B.C.
Edith	6.2	38	71	9	93	68	32	8	89	72	58	37	18	7	25	36	24	8	11	17	14	21	19	18	E.
Finley	4.6	31	66	9	90	67	29	8	87	70	55	32	18	10	23	38	21	8	13	17	15	23	14	18	F.
Mary (Papoose)	5.5	23	61	9	92	69	34	9	90	73	56	38	21	8	23	35	25	9	10	17	17	18	17	21	M.
Trout	4.0	28	62	10	95	69	28	7	91	74	56	35	15	5	26	41	21	7	9	17	18	21	20	15	Pt.
Black Oak	5.8	34	69	10	92	66	30	8	89	70	54	34	16	8	26	36	22	8	11	19	16	20	18	16	B.O.
Muskellunge	5.1	31	63	10	89	68	27	8	88	70	55	36	18	11	21	41	19	8	12	18	15	19	18	18	Mk.
Moon	5.4	31	64	10	91	69	31	10	88	72	57	36	18	9	22	38	21	10	12	16	15	21	18	18	Mn.
Nelson	5.0	31	63	10	91	66	29	10	87	68	54	35	17	9	25	37	19	10	13	19	14	19	18	17	Ne.
Silver	7.0	31	73	11	91	66	29	6	88	70	51	34	16	9	25	37	23	6	12	18	19	17	18	16	Si.
Little Bass	7.7	30	73	12	89	61	29	7	84	62	51	31	17	11	28	32	22	7	16	22	11	20	14	17	L.B.
Lit. Tomahawk	4.5	24	64	12	92	70	32	8	89	72	58	36	18	8	22	38	24	8	11	15	14	22	18	18	L.T.
Alma	3.8	26	60	16	93	84	33	9	91	76	60	37	18	7	9	51	24	9	9	17	16	23	19	18	Am.
Kawaguesaga	3.9	26	58	16	94	73	33	8	91	80	60	37	19	6	21	40	25	8	9	11	20	23	18	19	Ka.
Little John	2.6	16	38	17	95	82	40	10	95	85	68	45	27	5	13	42	30	10	5	10	17	23	18	27	L.J.
Macdonald	5.1	21	52	17	93	77	36	8	90	80	63	39	20	7	16	41	28	8	10	10	17	24	19	20	Mc.
Plum	5.7	26	58	17	96	73	30	8	93	73	58	35	19	4	13	43	22	8	7	20	15	23	16	19	Pl.

TABLE II

Distribution of solar radiation found in lakes at depth of one meter.

A. Lakes	B. General Data				Per Cent of Total Radiation Found at Intersection of Curve with Spectral Lines Indicating									Percent of Total Radiation Found Within Regions Indicated											Lake
					C. Wave-lgth. 000Å Omitted				D. Junction of Colors					E. By Wave-lgth. 000Å Omitted					F. By Color Regions						
	Trp. M.	% at 1 M.	Trm. %	Color	4	5	6	7	V-B	B-G	G-Y	Y-O	O-R	3–4	4–5	5–6	6–7	7–8	V	B	G	Y	O	R	
White Sand.......	3.7	17	50	18	93	72	32	7	90	74	57	36	18	7	11	40	25	7	10	16	17	21	18	18	W.S.
Jag.............	2.7	24	54	19	94	71	31	7	91	76	61	37	20	6	13	40	24	7	9	15	15	24	17	20	Jg.
Big.............	3.0	18	44	22	97	80	37	10	95	82	63	41	24	3	17	43	27	10	5	13	19	22	17	24	Bg.
Lit.Crooked	2.1	14	37	23	94	80	37	10	93	81	67	41	22	6	14	43	27	10	7	12	14	26	19	22	L.C.
L. St. Germaine...	2.2	21	43	24	98	83	38	8	97	87	67	43	20	2	15	45	30	8	3	10	20	24	23	20	LSG
Fishtrap..........	2.7	17	46	27	97	88	42	11	96	92	73	48	24	3	9	46	31	11	4	4	19	25	24	24	Ft.
High.............	3.1	14	45	27	96	81	40	11	93	84	69	46	23	4	15	41	29	11	7	9	15	23	23	23	Hi.
Spider...........	3.2	17	39	27	97	82	41	11	95	86	69	47	24	3	15	41	30	11	5	9	17	22	23	24	Sp.
Midge............	4.1	19	46	29	98	85	45	12	96	86	74	52	28	2	13	40	33	12	4	10	12	22	24	28	Md.
B. St. Germaine...	0.9	5	25	30	98	87	47	15	98	90	77	54	31	2	11	40	32	15	2	8	13	23	23	31	BSG
Adelaide..........	3.2	18	40	34	100	87	44	14	100	89	76	50	26	0	13	43	30	14	0	11	13	26	24	26	Ad.
Lit. Papoose......	2.3	17	43	36	100	87	43	14	97	88	77	48	28	0	13	44	29	14	3	9	11	29	20	28	L.P.
Found...........	1.2	18	46	37	98	90	50	15	97	91	80	58	30	2	8	40	35	15	3	6	11	22	28	30	Fd.
Bragonier.........	1.9	14	28	40	97	88	46	12	97	90	77	54	27	3	9	42	34	12	3	7	13	23	27	27	Br.
George...........	4.0	18	46	40	99	88	47	13	97	90	76	53	27	1	11	41	34	13	3	7	14	23	26	27	Ge.
Allequash.........	1.7	11	21	49	98	88	43	13	97	90	78	53	25	2	10	45	30	13	3	7	12	25	28	25	Aq.
Tenderfoot.......	3.0	15	40	49	100	87	50	15	100	91	74	57	31	0	13	37	35	15	0	9	17	19	25	30	Td.
Helen............	1.3	4.6	15	97	100	92	69	34	100	92	86	73	54	0	8	23	35	34	0	8	6	13	19	54	He.
Little Long.......	2.0	5.4	21	105	100	95	72	21	100	95	89	75	43	0	5	23	51	21	0	5	6	14	32	43	L.L.
Lit. Pickerel......	1.7	4.9	10	136	100	94	77	36	100	94	90	82	50	0	6	17	41	36	0	6	4	8	32	50	L.P.
Mary............	1.7	4.0	13	123	100	97	78	30	100	97	94	82	54	0	3	19	48	30	0	3	3	12	28	54	My.

TABLE III

Changes of distribution of radiation with increase of depth.
The data of this table are shown in figs. 19 and 20.
Numbers indicate percent of total radiation found in each color.

Lake	Depth M.	V	B	G	Y	O	R
Crystal	1	18	16	15	18	18	15
Color 0	3	16	22	20	22	12	8
	5	16	20	27	23	10	4
	7	14	25	27	23	10	1
	9	14	24	30	24	8	—
Day	1	14	20	16	20	15	15
Color 0	3	13	20	21	24	14	8
see p. 409	5	11	21	25	26	13	4
	7	8	22	30	27	13	—
	9	5	21	38	29	7	—
Black Oak	1	11	19	16	20	18	16
Color 10	3	9	14	21	29	18	9
	5	5	15	24	33	17	6
	7	2	16	25	37	17	3
	9	—	5	25	34	16	—
Silver	1	12	18	19	17	18	16
Color 11	3	11	15	21	25	18	10
	5	7	17	24	31	17	4
	7	3	17	29	36	13	2
Edith	1	11	17	14	21	19	18
Color 9	3	10	16	20	23	19	12
	4	9	15	22	30	17	7
	5	7	16	29	33	11	4
White Sand	1	10	16	17	21	18	18
Color 18	3	5	7	22	33	20	13
Kawaguesaga	1	9	11	20	23	18	19
Color 16	3	5	9	22	32	21	11
	5	3	8	23	41	22	3
Midge	1	4	10	12	22	24	28
Color 29	2	—	7	13	24	39	17
	3	—	3	9	30	39	19
Adelaide	1	—	11	13	26	24	26
Color 34	3	—	4	14	28	35	19
George	1	3	7	14	23	26	27
Color 40	3	—	3	11	30	32	24
Tenderfoot	1	—	9	17	19	25	30
Color 49	3	—	5	9	26	40	20
Little Papoose	1	3	9	11	29	20	28
Color 36	2	—	7	17	22	26	28
	3	—	4	20	25	28	33
Little Long	1	—	5	6	14	32	43
Color 105	2	—	3	5	4	32	56
Mary	1	—	3	3	12	28	54
Color 123	1.5	—	—	2	8	35	55
2m. computed	2	—	—	—	5	40	55

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COPEPODS PARASITIC ON FISH OF THE TROUT LAKE REGION, WITH DESCRIPTIONS OF TWO NEW SPECIES.

RUBY BERE

Notes from the Limnological Laboratory of the Wisconsin Geological and Natural History Survey. No. XLIV.

During July and August of 1930 quite extensive fishing operations were carried on from the Trout Lake Limnological Laboratory by the Wisconsin Geological and Natural History Survey and the U. S. Bureau of Fisheries. It was not possible to examine all the fish that were caught during this period but an attempt was made to examine some fish from the different lakes that were visited by the fishermen. Ten lakes are represented in the collection, all quite close to Trout lake. Though few in number, these lakes present considerable variation in their chemical, physical and biological characters. (See Table I).

Fish parasitized with copepods were found in only five of the lakes and these were, in no case, heavily infested. Thirteen hundred fish were examined, of which not quite two and one-half per cent. proved to be parasitized. The number of each species of fish which were parasitized is shown in Table II. The only copepod found in any number was *Ergasilus confusus,* which occurred on lake trout, whitefish, yellow perch, wall-eyed pike, small-mouthed black bass, and rock bass. In addition to this species, two specimens of *Achtheres coregoni* from a cisco (Trout L.) one specimen of *A. micropteri* from a small-mouthed black bass (Silver L.), and two specimens of *Argulus biramosus* from a yellow perch (Little Star L.) were obtained.

It is interesting to note that all species of fish caught in Trout L., with the exception of the sucker, were parasitized with *Ergasilus confusus;* in Muskellunge, Allequash and Silver lakes, this species of copepod also occurred but it was found only on certain species of fish. In Muskellunge, it occurred on yellow perch but not on rock bass or small-mouthed black bass; in Allequash, on rock bass but not on cisco, yellow perch, wall-eyed pike or small-mouthed black bass; and in Silver, on cisco and yellow perch but not on rock bass or small-mouthed black bass.

TABLE I

Chemical data for the lakes from which fish were examined for parasitic copepods.

Lake	pH	CO_2 Free	CO_2 Fixed	Conductivity	Residue	Plankton	Parasitic Copepods
Allequash	8.6	1.75	16.5	61	56.81	1.42	*Ergasilus confusus*
Silver	7.7	0.75	15.5	64	47.79	1.17	*Ergasilus confusus* *Achtheres micropteri*
Trout	7.6	1.0	16.5	70	58.20	0.82	*Ergasilus confusus* *Achtheres coregoni*
Muskellunge	7.5	0.5	9.0	41	35.56	1.18	*Ergasilus confusus*
Little Star	7.1	3.5	16.5	64	56.28	2.78	*Argulus biramosus*
Nelson	7.1	1.0	9.5	37	32.78	1.19	—
Nebish	6.6	0.5	5.2	22	22.60	0.40	—
Weber	6.3	1.0	1.7	9.3	12.64	1.13	—
Crystal	6.3	1.25	1.5	10	12.64	0.64	—
Geneva	5.4	1.0	1.0	10	19.88	2.02	—

As already mentioned, no parasitic copepods were obtained from the fish caught in five of the lakes, viz. Nelson, Crystal, Weber, Nebish and Geneva. From these lakes 30, 13, 172, 95 and 32 fish, respectively, were examined. The data on hand are, of course, too meagre to permit of any definite statements, but it might be pointed out that, whereas the pH of these five lakes ranges from 5.4 to 7.1, the pH of the lakes, with the exception of Little Star, in which parasitic copepods were found ranges from 7.5 to 8.6. The pH of Little Star L., in which *Argulus biramosus* but not *Ergasilus confusus* occurs is 7.1 (See Table I).

Both *Argulus biramosus* and *Ergasilus confusus* are new species and are herewith described.

Argulus biramosus n. sp.

PLATE IX, fig. 1-7

Two specimens of this species, both females, were found on the body of a yellow perch caught in Little Star L. These are recorded in the United States National Museum under Cat. No. 63831. This perch was gilled along with some hundred other perch and a few other fish but no other copepods were found.

TABLE II

Giving the number of fish examined and the number parasitized in Trout, Silver, Muskellunge, Allequash, Little Star, Crystal, Weber, Nelson, Nebish and Geneva Lakes. E = number of fish examined. P = number of fish parasitized.

Lake	Lake Trout		Cisco		White-fish		Sucker		Muskel-lunge		Yellow Perch		Wall-eyed Pike		Small-mouthed Black Bass		Sun-fish		Blue-gill		Rock Bass		Bull-head	
	E	P	E	P	E	P	E	P	E	P	E	P	E	P	E	P	E	P	E	P	E	P	E	P
Trout	15	2	210	10	4	1	4	0	..	..	50	*	6	*	1	1	..	..	..	..	64	*	..	..
Silver	..	..	56	7	..	..	4	0	..	..	21	3	..	..	5	1	..	..	..	..	25	0	..	..
Muskellunge	..	..	..	..	..	..	1	0	..	..	66	2	..	..	1	0	..	..	153	0	65	0	..	..
Allequash	..	..	14	0	..	..	4	0	..	..	13	0	3	0	1	0	..	..	1	0	8	*	..	..
Little Star	..	..	..	..	..	..	..	..	3	0	99	1	2	0	..	..	3	0	2	0	..	..	1	0
Crystal	4	0	..	..	..	..	..	..	..	..	5	0	..	..	4	0	..	..	..	..	..	..	..	..
Weber	..	..	..	..	..	..	..	..	..	..	170	0	..	..	2	0	..	..	..	..	..	..	..	..
Nelson	..	..	..	..	..	..	..	..	..	..	5	0	..	..	..	..	..	..	..	..	25	0	..	..
Nebish	..	..	..	..	..	..	..	..	..	..	24	0	..	..	4	0	..	..	..	..	67	0	..	..
Geneva	..	..	..	..	..	..	..	..	..	..	32	0	..	..	..	..	..	..	..	..	0	0	..	..

* = No record of number of fish parasitized.

Specific characters of female. Carapace slightly longer than wide, not quite reaching the base of the abdomen (fig. 1). Posterior sinus almost one-third the length of the carapace and twice as long as wide. The antero-lateral sinuses are not well developed and, consequently, the cephalic area projects only slightly. The second and third free thoracic segments are of equal length but slightly shorter than the first free segment. The last segment is about half the length of the preceding one. The outer respiratory areas are large, and run parallel with the margin of the carapace; the inner ones are small and circular and inserted in the inner margin of the outer ones, towards the anterior end (fig. 2). The abdomen is spindle-shaped with pointed lobes and about one-third the length of the rest of the body. The anal sinus is about half the length of the abdomen. The anal papillae, which are truncated posteriorly and fringed with setae, are lateral in position but not far removed from the anterior end of the sinus (fig. 3).

The first antennae are peculiar. Arising from the distal end of the second segment of the terminal portion there is a short, three-segmented ramus, giving to this part of the antenna a biramous appearance (fig. 4) hence the species name *biramosus*.

The two basal joints of the second antennae are broad and short; the third joint is about equal to their combined length but is much narrower; the two terminal segments become progressively shorter and narrower. This appendage is well supplied with setae, those on the basal segments being borne on protuberances (fig. 5). Situated posteriorly to the antennae, on either side of the mid line, is a pair of slightly curved spines.

The sucking disks are moderately large, occupying about one-fifth the width of the carapace. The chitin ribs are made of two parts, the distal being twice the length of the more centrally situated portion but tapering to about half its width. The margin of the disk is serrated; interspersed amongst these projections are small, claw-like structures (fig. 6).

Except for the teeth on the basal joint, there is nothing striking about the maxillipeds. The teeth are very blunt and widely separated with almost parallel sides (fig. 7). Near these appendages are two spines, one blunt, the other peg-like.

The swimming legs, the first two of which bear flagella, extend considerably beyond the margin of the carapace. All four pairs have a row of plumose setae along their posterior border and their basal joints are partially covered with very small spines. The basal joint of the fourth pair of legs possesses a large boot-shaped lobe which extends considerably beyond the lateral margin of the abdomen.

Color (living material). Carapace creamy with scattered reddish blotches. Abdomen colorless with the semen receptacles green. Dorsal surface of thorax densely covered with dark green spots but leaving a narrow yellowish-green streak above the intestine. These spots extend forward beneath the carapace to the mouth. The eyes are a darker shade than the pigment spots of the carapace.

As already mentioned, two specimens of this species were obtained, upon one of which the above description is based. The second specimen differs from the one just described in three particulars: 1) the carapace extends a little beyond the base of the abdomen; 2) the lobe on the fourth leg extends only slightly beyond the margin of the abdomen; and 3) the second antennae have four segments instead of five and do not bear as many setae.

Ergasilus confusus n. sp.

PLATE X figs. 8-16

Occurrence. In Trout L. from yellow perch, wall-eyed pike, rock bass, small-mouthed black bass, lake trout, cisco and whitefish; in Muskellunge L. from yellow perch; in Allequash L. from rock bass; in Silver L. from cisco and yellow perch.

No male specimens were obtained and the following description is based on a specimen taken from a wall-eyed pike caught in Trout L., Cat. No. 63833, U. S. N. M.

Specific characters of female. General body form elongate (fig. 8). Cephalothorax rectangular, a little more than one-third longer than wide, with rounded corners. Sides indented about two-thirds down. Antennal area triangular in outline and projecting considerably, permitting the exposure of the bases of the antennae. Both dorsal and ventral surfaces strongly convex with the mouth parts projecting considerably and situated two-thirds down between the anterior end of the animal and the posterior margin of the carapace. The first free thoracic segment abruptly narrowed to half the width of the carapace. The two succeeding segments are narrowed regularly backwards, the first one being about two-thirds the length of the first free thoracic segment, the second one again shorter. The fourth segment is very short and also narrower than the preceding segment. The first free segment bears a pair of lateral lobes. The genital segment is slightly wider than the fourth segment and barrel-shaped. Abdomen same width as fourth segment, three-jointed, the first joint slightly longer than the other two; anal laminae rectangular in outline, each armed with three setae, the inner one of which is much the longest. Egg strings elliptical, tapering a little posteriorly, a little over half the length of the entire body (figs. 8 and 9).

First antennae six-jointed and well supplied with setae (fig. 10). Basal joint of second antennae greatly swollen and projecting strongly on the outer margin; second joint with a small, sharp spine at the center of the inner margin; the third joint bears distally a rounded knob on its inner margin; terminal claw with two teeth-like projections on the inner margin (fig. 11). Mandibles large, with the terminal portion directed forwards; cutting blade provided with setae along the inner margin; palp long and armed with short spines on the inner margin; an extra palp, which is triangular in outline and armed with short spines along its outer margin, occurs at the distal end of the basal portion. The first and second maxillae are of the usual type; the cutting blade of the latter is also curved forwards and its terminal portion is profusely covered with spines (fig. 12).

With the exception of the exopod of the fourth pair of legs, which is two-jointed, all the rami of the first four pairs of legs are three-segmented. The arrangement of the spines and setae is shown in figures 13-16. Between the bases of the first, second, and third pairs of legs there occurs a row of short spines. The fifth pair of legs are vestigial, consisting of a single three-jointed spine-like ramus.

Color. A bright blue pigment spot is present just posterior to the eye. The lateral areas are similarly pigmented, as are also the bases of the legs. The rest of the body has a slight creamy tinge. Egg strings containing ripe eggs are a light blue. The species name *confusus*, indiscriminate, refers to the fact that the parasite is found on many hosts.

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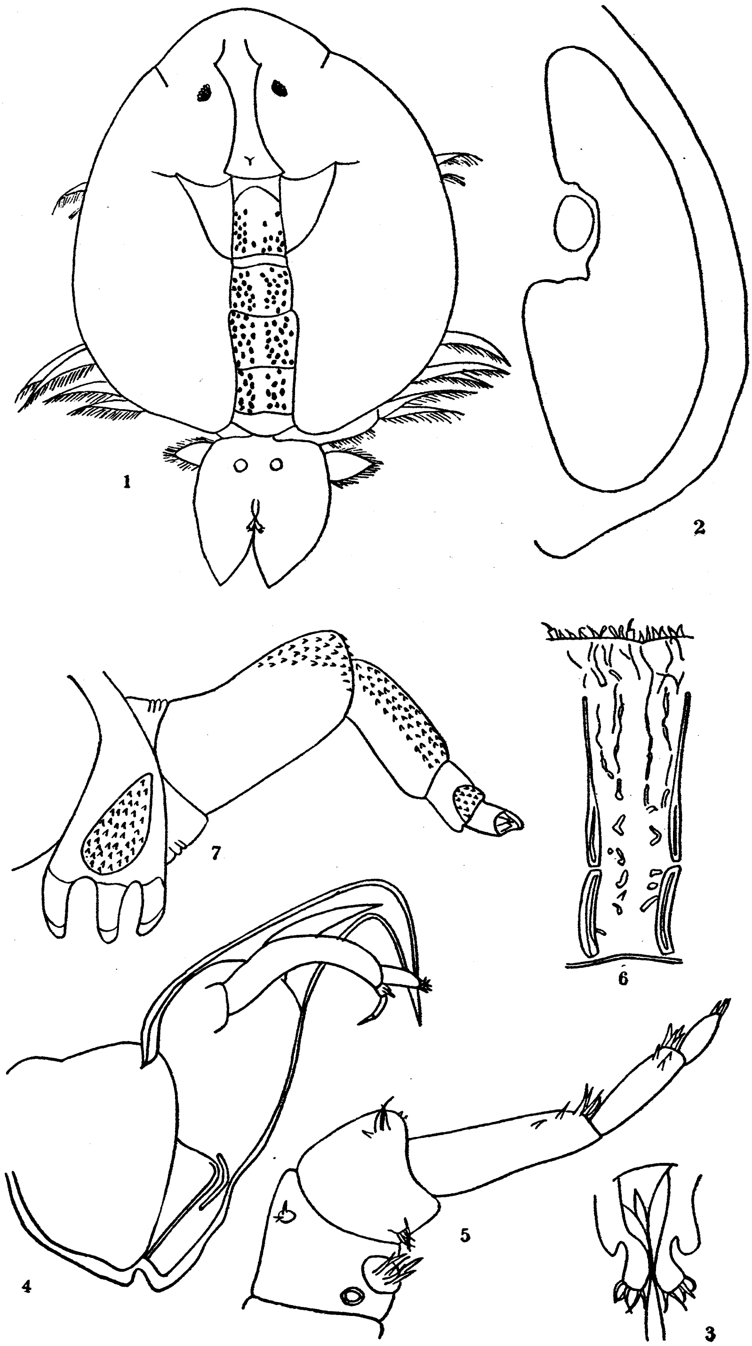
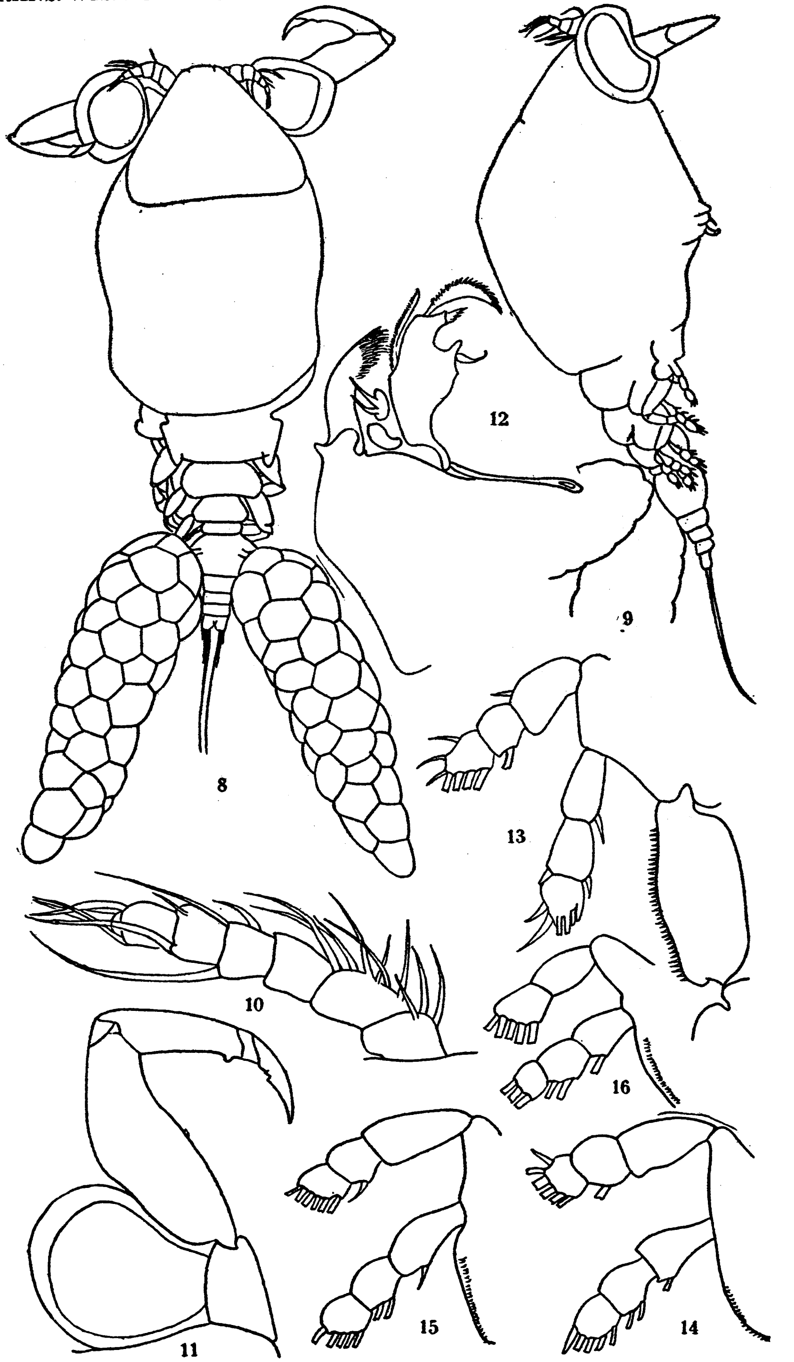
TRANS. WIS. ACAD. VOL. 26 PLATE IX



TRANS. WIS. ACAD. VOL. 26

PLATE X



EXPLANATION OF PLATES

Plate IX

Fig. 1. Dorsal view of *Argulus biramosus.*
Fig. 2. Respiratory areas.
Fig. 3. Anal papillae.
Fig. 4. First antenna.
Fig. 5. Second antenna.
Fig. 6. Chitin ribs supporting the margin of the sucking disk.
Fig. 7. Maxilliped.

Plate X

Fig. 8. Dorsal view of *Ergasilus confusus.*
Fig. 9. Lateral view.
Fig. 10. First antenna.
Fig. 11. Second antenna.
Fig. 12. Mouth parts.
Fig. 13. First swimming leg.
Fig. 14. Second Swimming leg.
Fig. 15. Third Swimming leg.
Fig. 16. Fourth Swimming leg.

LEECHES FROM THE LAKES OF NORTHEASTERN WISCONSIN

RUBY BERE

Notes from the Limnological Laboratory of the Wisconsin Geological and Natural History Survey. No. XLV.

The leeches upon which this paper is based were collected during July and August of 1930 while working at the Trout Lake Limnological Laboratory of the Wisconsin Geological and Natural History Society. The list is in no way complete for at many of the lakes it was possible to stop for only a few minutes.

The specimens were obtained by examining the under side of rocks, submerged twigs and logs, fish, clam shells, etc. In two instances, *Helobdella stagnalis* was found in bottom samples from Trout lake at six and seven m. respectively. *Placobdella rugosa* was also found on the writer and others on a number of occasions while swimming or collecting. The animals were attached between the toes, in the ankle region, and on the hands. *Haemopis grandis* was quite often observed swimming during the day in Trout lake, probably disturbed by our own swimming activities for leeches are, as a rule, nocturnal in habit.

Of the free-living leeches, *Placobdella montifera* and *P. phalera* were also taken from fish. Their occurrence as parasites is shown in Table I. *P. phalera* was found only once, being attached to the gill arch of the host. *P. montifera* was found on the caudal fin and near the operculum of its hosts. *P. pediculata* is reported by Moore from Minnesota lakes as a nearly permanent fish parasite. However, in addition to the two specimens taken from just inside the operculum of a sucker caught in Trout L., a single specimen of this species was found on the under side of a rock in Allequash L. *Piscicola punctata* was not found free-living although it has often been taken independently of its hosts. It occurred on the body, on the caudal and pectoral fins, and on the roof of the mouth of its hosts. A single specimen of *Piscicola geometra,* another of the fish leeches, was

TABLE I

Showing the fish upon which leeches were found and the lakes in which they occurred.

	Sucker	Yellow Perch	Small-mouthed Black Bass	Bluegill	Rock Bass
Placobdella phalera	—	—	—	Muskellunge	—
P. montifera	—	Little Star	—	—	Muskellunge
P. pedicu-lata	Trout	—	—	—	—
Piscola punctata	—	Muskellunge Silver Little Star	Silver	Muskellunge	—

found clinging to one of the gill nets which had been set in Trout L. It was not observed on any fish.

A total of eighteen species was collected. This number compares very well with the twenty-one species recorded from Minnesota in 1912 in "The Leeches of Minnesota", which probably represents years of collecting, and the fourteen species obtained in Illinois over a period of 25 years and reported in 1901 in "The Hirudinea of Illinois".

A systematic list of the species follows:

Class HIRUDINEA

Suborder RHYNCHOBDELLAE

Family GLOSSIPHONIDAE

Genus *Glossiphonia* Johnston

Glossiphonia complanata (Linn.).

Allequash, Arbor Vitae, Ballard, Big Carr, Island, Little Papoose, Little Star, Trout, White Sand, and the Manitowish R.

Glossiphonia heteroclita (Linn.).

Allequash, Mann, and Trout.

Genus *Helobdella* R. Blanchard.

Helobdella stagnalis (Linn.).

Allequash, Arbor Vitae, Ballard, Bass (Flambeau), Birch, Black Oak, Boulder, Geneva, George, Irving, Jag Island, Laura, Little Papoose, Little Star, Little Tomahawk, Long (Pokegama), Lost Canoe, Mann, Muskellunge, Nebish, Razor Back, Silver, Trout, Upper Gresham, White Birch, White Sand, White Cat, Manitowish R., and Cardinal Bog.

Helobdella fusca (Castle).
Little Star, Little Papoose, Razor Back, Silver.

Helobdella nepheloidea (Graf).
Ballard, Geneva, Little Papoose, Nebish, White Sand, Wild Cat.

Genus *Placobdella* R. Blanchard.

Placobdella rugosa (Verrill).
Allequash, Arbor Vitae, Ballard, Fliegel, Geneva, Island, Kawaquesaga, Little Star, Little Star (Woodruff), Lost Canoe, Mary, Muskellunge, Pallette, Sterrett, Trout, White Sand, and Manitowish R.

Placobdella parasitica (Say).
Allequash, Geneva, and Manitowish R.

Placobdella montifera Moore.
Allequash, Ballard, Black Oak, Little Star, Muskellunge, Trout, and outlet of Little Star (Woodruff).

Placobdella phalera (Graf).
Allequash, Island, Laura, Little Long, Little Star, Muskellunge, Nelson, White Birch, and Manitowish R.

Placobdella picta (Verrill).
Crystal, Geneva, Little Long, Little Papoose, Mann, Mary, Muskellunge, Nelson, and White Sand.

Placobdella pediculata Hemingway.
Allequash, Trout.

Family ICHTHYOBDELLIDAE

Genus *Piscicola* Blainville

Piscicola punctata Verrill.
Little Star, Muskellunge, Silver, Trout.

Piscicola geometra Linn.
Trout.

Suborder GNATHOBDELLAE

Family HIRUDINIDAE

Genus *Haemopis* Savigny.

Haemopis marmoratis (Say).
Lost Canoe, Trout.

Haemopis grandis (Verrill).
Allequash, Ballard, Little Papoose, Lost Canoe, Mann, Silver, Trout, and outlet of Muskellunge.

Family ERPOBDELLIDAE

Genus *Erpobdella* Blainville.

Erpobdella punctata (Leidy).

Adelaide, Allequash, Arbor Vitae, Ballard, Bass (Flambeau), Big Carr, Black Oak, Boulder, Constance, Crystal, Favil, Fliegel, Geneva, George, Island, Kawaquesaga, Little Long, Little Papoose, Little Star, Little Star (Woodruff), Little Tomahawk, Long (Pokegamma), Lost Canoe, Mann, Mary, Muskellunge, Nebish, Nelson, Pallette, Pokegamà, Ross Allen, Silver, Trout, Weber, White Birch, White Sand, Manitowish R., and outlet of Little Sar (Woodruff).

Erpobdella punctata annulata Moore.

Arbor Vitae, Little Star.

Genus *Nephelopsis* Verrill.

Nephelopsis obscura Verrill.

Allequash, Arbor Vitae, Ballard, Bass (Flambeau), Big Carr, Birch, Black Oak, Crystal, Fliegel, Geneva, Irving, Kawaquesaga, Little Papoose, Little Star, Little Tomahawk, Long (Pokegama), Lost Canoe, Mann, Nebish, Pallette, Rock, Ross Allen, Trout, White Sand, Wild Cat, and Manitowish R.

Genus *Dina* R. Blanchard.

Dina parva Moore.

Ballard, Arbor Vitae, Birch, Muskellunge, Trout.

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NOTE ON THE DETERMINATION OF TOTAL PHOSPHORUS IN LAKE WATER RESIDUES

LESLIE TITUS AND VILLIERS W. MELOCHE

Contribution from the Laboratory of Analytical Chemistry, University of Wisconsin, and Notes from the Limnological Laboratory of the Wisconsin Geological and Natural History Survey. No. XLVI.

In the method presented by Juday, Birge, Kemmerer, and Robinson in 1928[1] and in the slightly modified procedure presented by Robinson and Kemmerer in 1930[2] the sample of lake water to which sulfuric, hydrocholoric, and nitric acids have been added is evaporated to fumes of sulfuric acid anhydride. In this evaporation the authors caution against the loss of SO_3 fumes, stating that phosphorus will be lost if these fumes are allowed to pass out of the flask. The use of the modified procedure on many samples has made it apparent that there exists a temperature range in which digestion can be made without danger of the loss of phosphorus even though fumes of $S0_3$ are allowed to escape. The following note serves to illustrate this point as well as to give certain details regarding the digestion of samples.

In order to test the possible loss of phosphorus upon digestion, a standard solution of potassium di-hydrogen phosphate (KH_2P0_4) was prepared which contained 0.001 mg of phosphorus per cubic centimeter. Portions of this solution were used as standards and equal portions were used as samples. To each portion used as a sample were added 3 cc of HCl, 0.5 cc of HNO_3, and 0.2 cc of H_2SO_4 just as was done with lake water residues. Following the digestion of the samples described in the following table, the phosphorus content was estimated by the usual color comparison with the untreated standards.

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[1] Wis. Acad. Sci., Arts and Letters Vol. XXIII, 233, 1928.
[2] Wis. Acad. Sci., Arts and Letters Vol. XXV, 117, 1930.

TABLE I

Sample No.	Phosphorus added	Phosphorus found	Conditions of Digestion
1	0.005 mg	0.0049 mg	130° to 160°C No fumes of SO_3 escape
2	0.005	0.0050	Fumed 50 minutes at 160°C
3	0.005	0.0052	Fumed 20 minutes at 160°C
4	0.005	0.0051	Fumed 2 hours at 160–170°C
5	0.005	0.0052	Fumed 2 hours at 160–170°C
6	0.005	0.0051	Fumed 15 minutes 180–210°C Considerable H_2SO_4 lost
7	0.005	0.0051	Fumed 55 minutes 210–220°C Considerable H_2SO_4 evaporated
8	0.005	0.0035	Fumed 1 hour at 210–220°C *H_2SO_4 completely evaporated*
9	0.005	0.0050	Fumed 25 minutes. Temperature during last 15 minutes–210°C Part of the H_2SO_4 evaporated

Digestions were made in 50 cc Erlenmeyer flasks which were heated in an air bath the temperature of which could be controlled within ± 5°.

Since many of the lake residues examined contained more phosphorus than that represented in the above table it seemed desirable to repeat the experiments using a greater initial concentration of phosphorus. These results are given in Table II.

TABLE II

Sample No.	Phosphorus added	Phosphorus found	Conditions of Digestion
10	0.025 mg	0.026 mg	Temperature 180°C Fumed 20 minutes
11	0.025	0.025	Fumed 10 minutes 180°C
12	0.025	0.025	Fumed 10 minutes at 180°C
13	0.025	0.023	0.7 cc H_2SO_4 used and evaporated to about 0.2 cc Evaporated 4 hrs. at 200°
14	0.025	0.025	Fumed 10 minutes at 160°
15	0.050	0.051	Fumed 10 min. at 180°
16	0.050	0.050	Fumed 10 min. at 180°
17	0.050	0.050	Fumed 20 min. at 210°
18	0.050	0.050	Fumed 20 min. at 210°

After digestion the above samples were diluted to 100 cc. One-fifth aliquot of samples 10 to 14, inclusive, and one-tenth aliquot of samples 15 to 18, inclusive, were used to make the color comparison. Because of the dilution of the digested samples, the original amount of sulfuric acid did not have much effect on the color produced.

It has been suggested that the presence of organic matter plays some part in the possible loss of phosphorus during digestion of the sample. Since the samples reported in Tables I and II contained no organic matter, it was decided to complete several digestions of the standard potassium di-hydrogen phosphate to which had been added small portions of pure sucrose. The estimations of phosphorus in these samples are given in Table III.

TABLE III

Sample No.	Phosphorus present	Phosphorus found	Sucrose present	Conditions of Digestion
1	0.025 mg	0.025 mg	2.5 mg	All samples digested at 170–180°C and allowed to fume several minutes. A second addition of 3 cc H_2O, 3 cc HCl, and 0.5 cc HNO_3 was made to each sample in order to accomplish complete oxidation.
2	0.025	0.025	2.5	
3	0.025	0.025	2.5	
4	0.025	0.025	5.0	

In using the Denigés ceruleomolybdate reaction for the estimation of phosphorus it should be noted that it has been previously shown that the presence of a relatively small excess of sulfuric acid will inhibit the development of a color after the molybdate reagent has been added. If an excess of sulfuric acid has been used in the digestion of the sample, it obviously must be removed by evaporation before the usual color comparison can be made. This consideration is not to be confused with the one at hand, namely, the possible loss of phosphorus during the digestion.

From the data in Tables I and II it is apparent that the condition for digestion of the sample may be so controlled that there will be no loss of phosphorus by evaporation even though SO_3 fumes are allowed to escape. The results in Table III indicate that organic matter may be oxidized under these conditions of digestion without the loss of phosphorus.

The following conditions are, therefore, recommended for the digestion of samples of lake water residues in the determination of total phosphorus. The residue sample is treated with 10 cc of distilled water, 0.2 cc H_2SO_4, 3 cc HCl, and 0.5 cc HNO_3. The convenient container is a 50 cc Erlenmeyer flask.

The main part of the water is removed by evaporation and the remaining acid solution is digested at a temperature of 170 - 180° in an air bath. If the sulfuric acid solution is not clear at the end of a few minutes digestion or at the time the HNO_3 and HCl have been removed, another portion of 3 cc HCl and O.5 cc HNO_3 may be added and the digestion repeated. *In either case there must be a slight excess of sulfuric acid at the end of the digestion and the HNO_3 must be completely removed.* The sample is then ready for color comparison with the known standard.