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The *Transactions* welcomes sound original articles in the various fields of science and scholarship by members of the Wisconsin Academy of Sciences, Arts and Letters. Manuscripts should be addressed to James A. Larsen, Observatory Hill Office Building, University of Wisconsin, Madison 6, Wisconsin. Manuscripts should be double-spaced throughout, and should have the address to which proofs are to be sent typed in the upper left-hand corner of the first page. Manuscripts for consideration should be in the hands of the editor by June to permit publication of the *Transactions* within the year.

A NINE-YEAR STUDY OF FALL WATERFOWL MIGRATION[1] ON UNIVERSITY BAY, MADISON, WISCONSIN

S. TENISON DILLON

PART II[2]

MIGRATION CHRONOLOGY

The average chronology of the fall waterfowl flight through University Bay for the years 1947–1954 inclusive is given in Figure 3. Data from 1946 are not included as they could not be broken down into weekly periods. The time intervals chosen follow those established by Jahn (1949). In order to include his data, it was necessary that I fit the remaining data to these periods. The initial period is nine days instead of a week in order to include the earliest starting date of this series (Jahn, 1949). The chronology is expressed as the per cent of the total flight per observation day plotted over a period of time that includes all the observations of any given year. Curves are presented for the Mallard and Black Duck, other dabbling ducks, Buffle-head, Ring-necked Duck, other diving ducks and Coot. The Mallard and Black Duck are considered together because of their ecological and numerical similarities on the Bay. The Ring-necked Duck, although ecologically similar to the dabbling ducks, is a diving duck that is "common" on the Bay and is an early migrant. The Buffle-head is also "common" on the Bay but migrates relatively late in the season. The Coot is treated separately because of its ecological and numerical independence on the Bay.

These curves show that a few individuals of at least five species of waterfowl are usually present on the Bay throughout the 80-day average observation period. The greater number of waterfowl are on the Bay from mid-October to late November during which time most species attain maximum numbers. The most persistent users of the Bay are Mallards and Black Ducks. The curve (Figure 3) shows what is apparently an extended migration period during six weeks of which high population levels are maintained. This partially reflects an actual population phenomenon, but it is also partly the result of combining eight years of data. This is shown in Figure 4 where we see that in only two of the four years involved (1951 and 1954) do the annual chronology curves approximate the eight-year-average curve.

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[1] Journal Paper No. 33, University of Wisconsin Arboretum.
[2] Continued from Volume 45.

I believe this trend toward an extended period of high population levels is the result of Mallards and Black Ducks remaining on the Bay once they have arrived. Burger (1954) gives evidence for what he believes to be a "local breeding population" of these species. He describes a site near the mouth of University Creek where "what

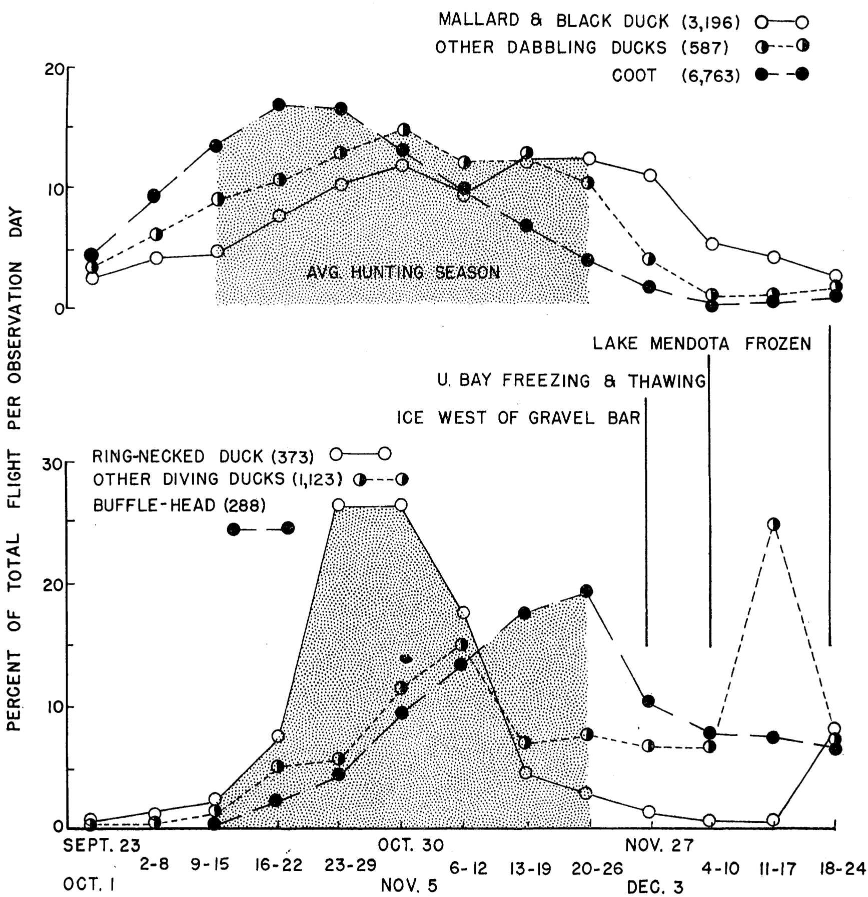

FIGURE 3. Eight-year average, 1947–1954, of the fall waterfowl flight through University Bay, Madison, Wisconsin. The total flight per observation day is given in parentheses.

was apparently a resident group of Blacks" were regularly found. He goes on to say: "Forty-five birds were observed here the first day and between 32 and 60 Blacks used the area in the same way and at the same times until well into November." With respect to Mallards at this location, Burger states: "From October 2 to November 27 a group of some 40 Mallards used this protected cove,

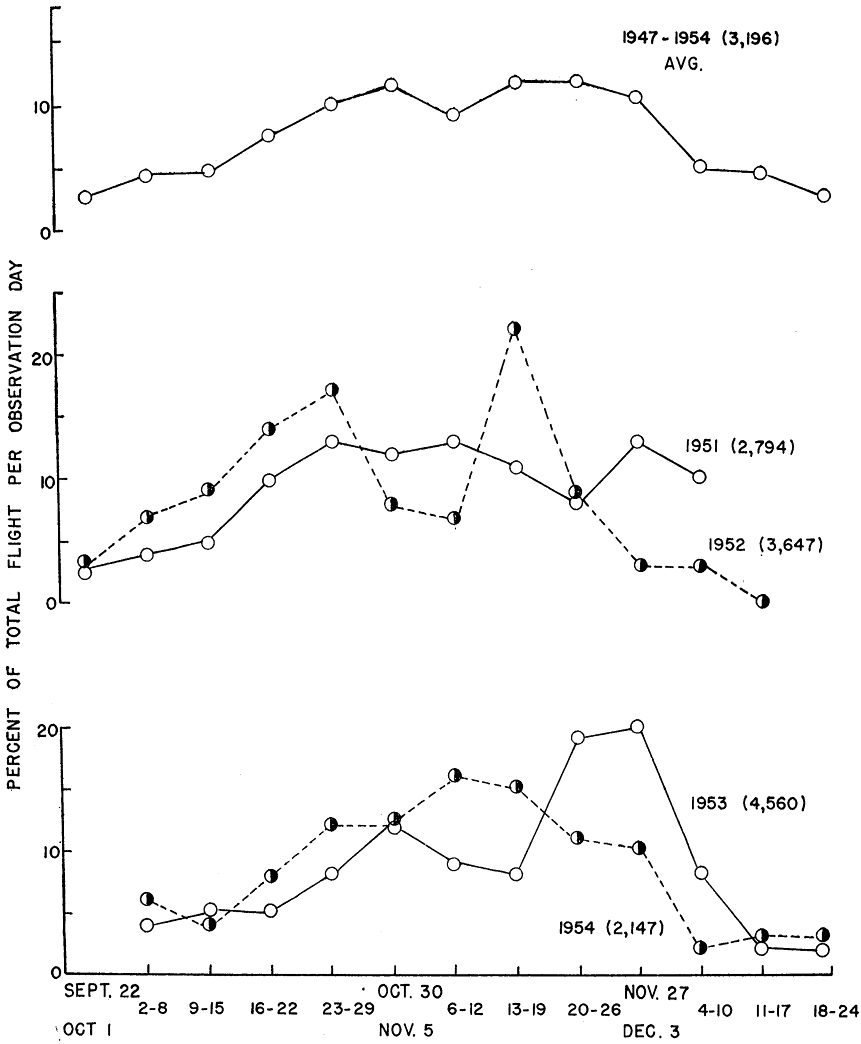

FIGURE 4. Chronology of the fall migration of the Mallard and Black Duck through University Bay, Madison, Wisconsin. The total flight per observation day is given in parentheses.

roosting on the shore and resting in the same area. The consistent numbers and a characteristically high number of males indicate that this was a resident group. In addition the flock behaved as a unit . . ." A similar group of ducks was also mentioned by Dzubin (1953).

Mallards and Black Ducks breed in the vicinity of the Bay. Nests have been found and broods observed by a number of people. It is very doubtful, however, that this "resident" group of eighty to one hundred Mallards and Black Ducks is made up of breeding pairs and their young. R. A. McCabe has told me of seeing at least six different broods on the Bay during June and July of 1952. This would place the breeding population at about a dozen ducks. J. J.

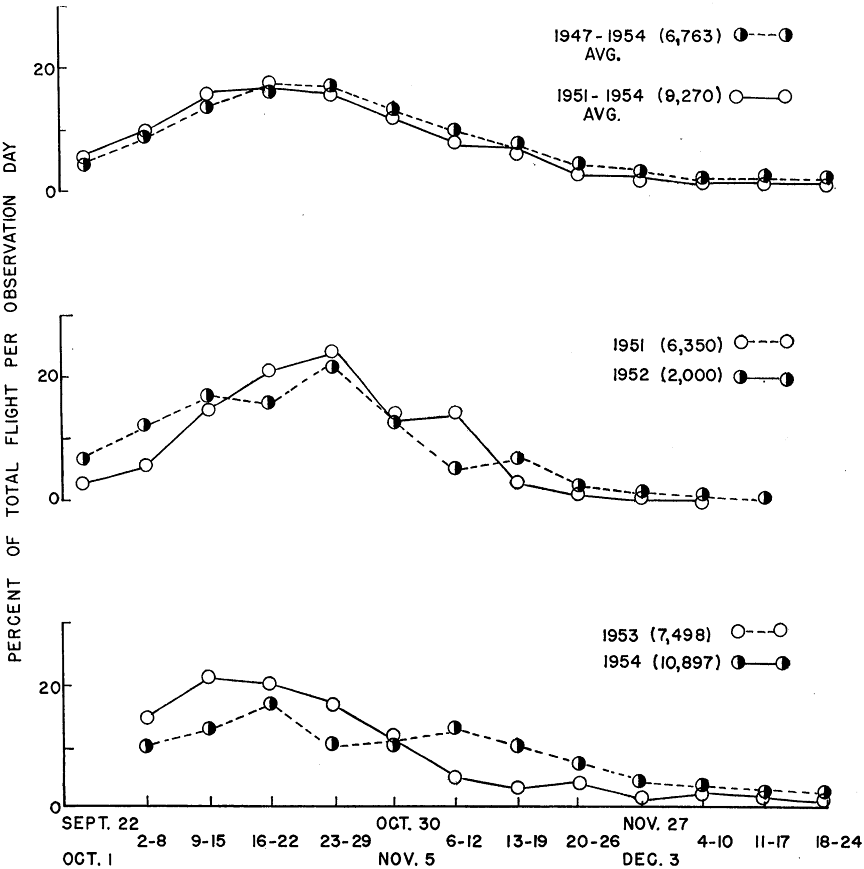

FIGURE 5. Chronology of the fall migration of the Coot through University Bay, Madison, Wisconsin. The total flight per observation day is given in parentheses.

Hickey has informed me that he has never seen more than about twenty Mallards and Black Ducks on the Bay during July and August. Since Burger's first counts were made on October 2, it seems likely that his "local breeding population" was well padded with migrants which had acquired a familiarity with the area and a "taste" for the food provided in the neighboring corn field. Regardless of their migratory status, it is probable that these ducks

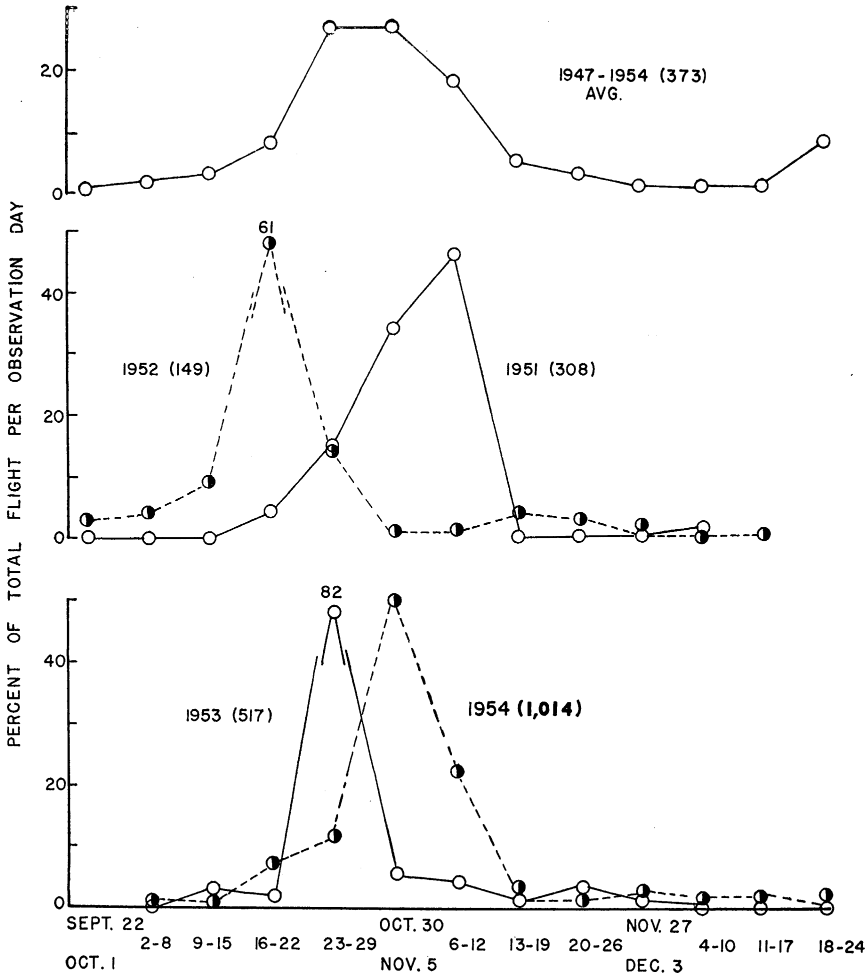

FIGURE 6. Chronology of the fall migration of the Ring-necked Duck through University Bay, Madison, Wisconsin. The total flight per observation day is given in parentheses.

would act as decoys to others of their kind, and, under the protection of the refuge, impart to them their "feeling of security" with the result that these newcomers would, themselves, be inclined to remain on the Bay. In this way the trend toward an extended period of high population levels in these species might be established.

The eight-year average migrational chronology for other dabbling ducks (largely Baldpate, Gadwall and Shoveller) is similar to that for the Mallard and Black Duck except that these species do not usually maintain high population levels on the Bay for as long a time as do the Mallards and Black Ducks (Figure 3). They do not stubble to the near-by cornfield and usually leave the Bay when skim-ice begins to form.

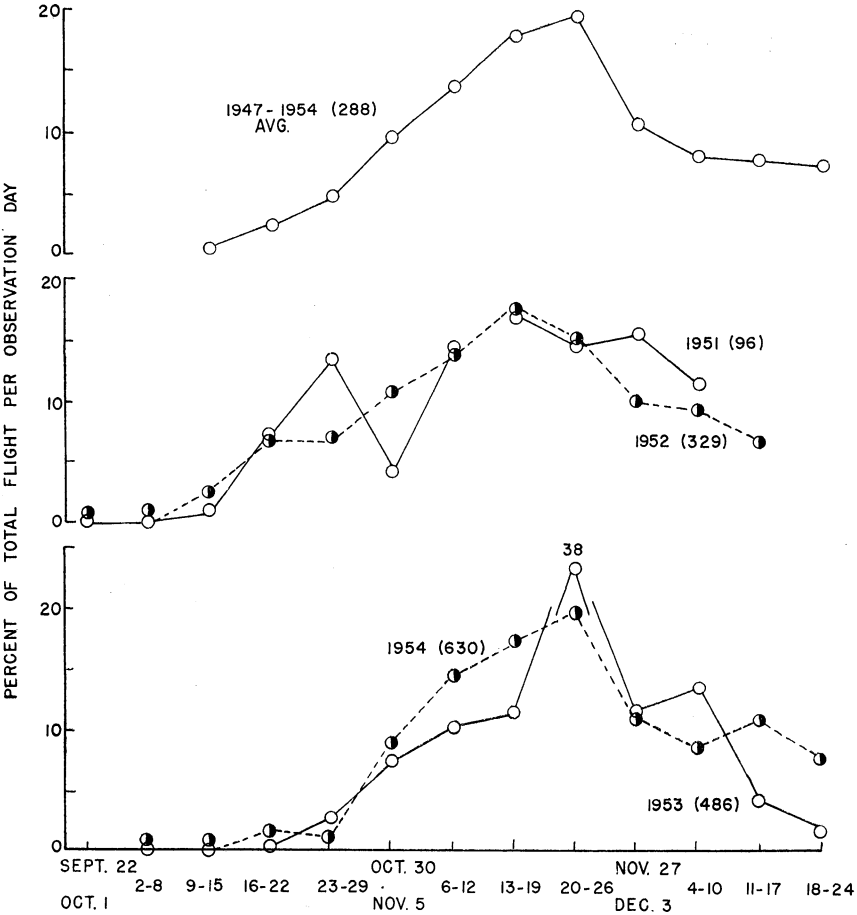

FIGURE 7. Chronology of the fall migration of the Buffle-head through University Bay, Madison, Wisconsin. The total flight per observation day is given in parentheses.

Coots are even more numerous on the Bay than are Mallards and Black Ducks, comprising about fifty-six per cent of the total number of waterfowl observed during this study. The chronology of their fall migration through the Bay is quite regular (Figure 5), more so than that of any other single species. This seems to support the statement of Murphy (1948) to the effect that migration [in

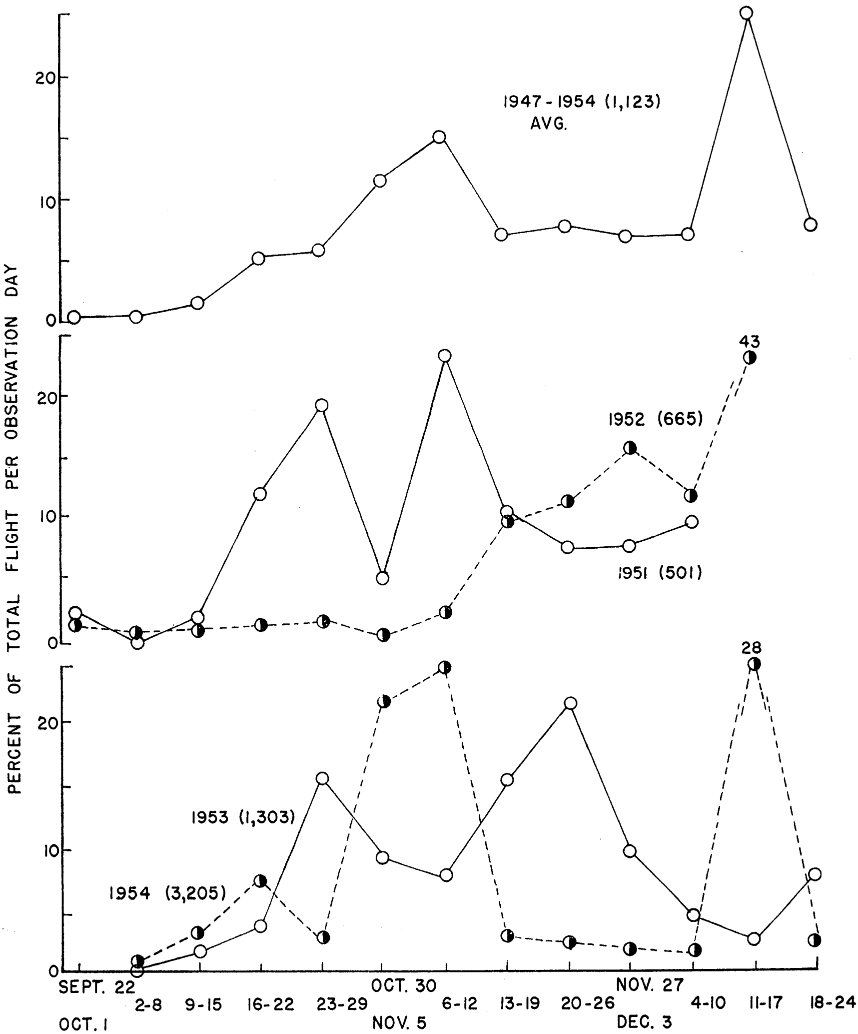

FIGURE 8. Chronology of the fall migration of other diving ducks (Redhead, Scaup sp., Canvas-back and American Golden-eye) through University Bay, Madison, Wisconsin. The total flight per observation day is given in parentheses.

birds] has become so thoroughly keyed to the seasons that the calendar, not conditions of food or temperature marks arrival and departure.

Among the diving ducks on University Bay, the Ring-necked Duck is usually the first to attain maximum numbers in the fall (Figure 3). The chronology of its main migration, however, is often much more rapid than the eight-year-average curve indicates

(Figure 6). Maximum numbers are usually reached in late October. They are apparently maintained only a few days before these ducks leave the Bay. A late-season population increase is indicated for this species in Figure 3. This suggests that a final flight of Ring-necked Ducks is to be expected on the Bay just prior to the freeze-up. The last-week increase of the eight-year-average curve, however, is the result of an extremely late migration peak in 1948 (239 Ring-necked Ducks observed during the week of December 18–24, representing 46 per cent of that year's total flight for that species) and is not characteristic of the general migration pattern of this species. This is also indicated in Figure 6.

The main flight of the Buffle-head appears on University Bay relatively late in the season (Figure 3). It is usually not as late as that of the American Golden-eye. Buffle-heads are normally first seen on the Bay during the third week of October. They attain maximum numbers during the last half of November after a population build-up that may be gradual or rather erratic (Figure 7). The population decline prior to the formation of ice is similar to its increase, although somewhat more rapid. During the observation periods of 1951, 1952 and 1953, 2,400 Buffle-head were counted on the Bay while only one was identified on Lake Mendota by aerial surveyors (Tables 3 and 4). Observations on University Bay will apparently provide a better estimate of the fall Buffle-head flight through the Madison area than the aerial surveys.

The migration of "other diving ducks" through University Bay (Figure 3) is made up largely of flights of Redheads, Scaup sp., Canvas-back and American Golden-eye. A few individuals of one or more of these species are usually present on the Bay throughout the 80-day average observation period. Migratory flights of these ducks may be expected any time between mid-October and mid-December (Figure 8), but the average trend is toward a population peak in early November. The earlier flights are usually made up of Redheads and Scaup sp. while the American Golden-eye is prominent among those ducks remaining on the Bay until the freeze-up. The marked late-season population increase shown in Figures 3 and 8 is largely the result of 1,634 Canvas-back recorded by Burger (1954) on December 12, 1954, and of 184 American Golden-eye recorded by Kiel (1948) on December 13, 1948. Such late-season flights, however, are not uncommon for this group of ducks. For example, Kiel (1948) noted 106 Scaup sp. on the Bay on December 24 when the greatest number he reported on any one day prior to this since December 1 had been seven. Dillon (1952) reported 224 American Golden-eye on December 12, which was the population peak of that species on the Bay for that year. In the case of this species, early freezes which eliminate observation days have considerable effect in "reducing" an annual population. This has been discussed by Kiel (1948) and Burger (1954).

Considering the chronologies of Figure 3, we see that the average, 42-day Wisconsin waterfowl season (1947–1954) includes the periods of high population levels in nearly all the species or groups

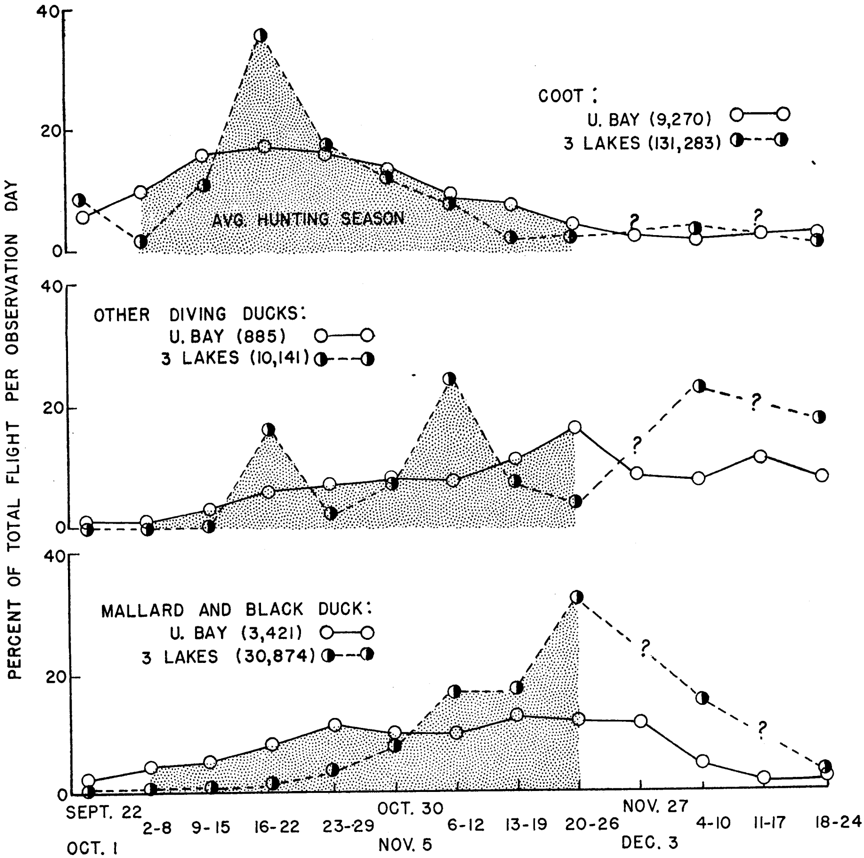

FIGURE 9A. Four-year average, 1951–1954, of the fall waterfowl flight through University Bay and three Madison-area lakes (Mendota, Waubesa and Kegonsa). The total flight per observation day is given in parentheses.

of species represented. Possible exceptions are the Buffle-head and American Golden-eye. These ducks, while not rejected, are probably not preferred by most Wisconsin gunners. There is also the indication that an additional week in November would increase the harvest of Mallards and Black Ducks.

The average chronology of the fall waterfowl flight through both University Bay and the "three lakes" for the years 1951–1954 in-

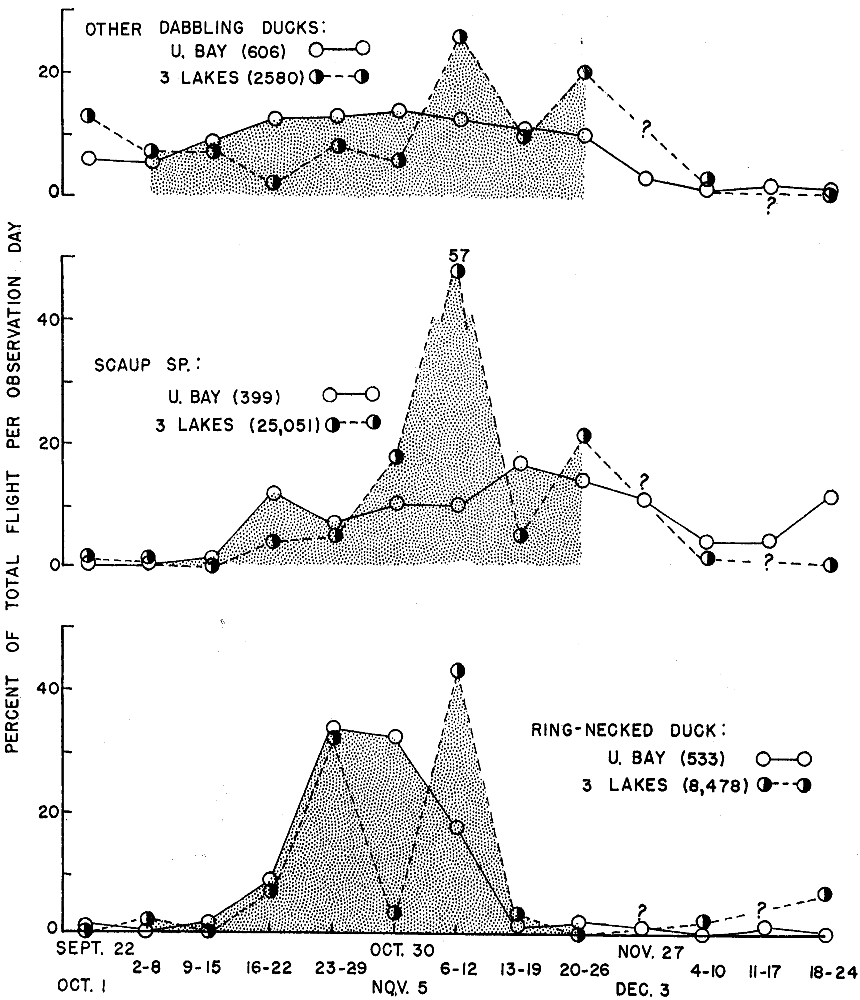

FIGURE 9B.

clusive is given in Figures 9A, B and C. Curves are presented for the Mallard and Black Duck, Coot and other dabbling ducks which consist largely of Baldpate, Gadwall and Blue-winged Teal. Among the diving ducks, the Ring-necked Ducks, Scaup sp. and Canvasback are singled out for special attention. This was done because these were the most numerous species common to both areas. The "other diving ducks" category consists largely of Redheads, Bufflehead, American Golden-eye and, in the case of the "three lakes", unidentified diving ducks.

Two things should be apparent upon examining Figures 9A, B and C with reference to Figure 3. One is that comparable curves in both the four- and eight-year average chronologies for University Bay (Mallard, Black Duck, Coot, Ring-necked Duck and other dabbling ducks) are similar in shape and position relative to the axes of ordination and abscissas. This at least indicates some degree of interyear consistency in the fall flights of the species involved. The species in which this is best represented is the Coot (Figure 5). We have, however, seen how individual years can differ from an average (Figures 4, 6, 7 and 8).

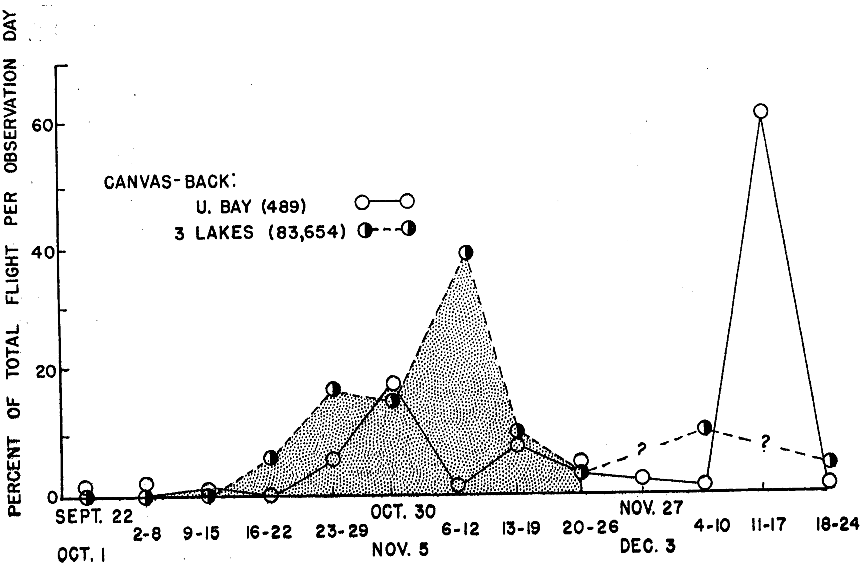

FIGURE 9C.

The second point is that the four-year curves for the "three lakes" show marked fluctuations which, in many cases, depart radically from the University Bay curves. We can compare these curves only in general terms because of the ecological differences in the areas and because, in fitting the "three lakes" data to the Bay time intervals, the weeks of November 27 to December 3 and December 11 to 17 were not represented at all. The position of the curves, therefore, during these weeks is not known. This makes it possible to define late November and December migration peaks on the "three lakes" only to the nearest two or three weeks.

These fluctuations, since they reflect the presence or absence of waterfowl on certain observation days, must depend upon movements both local and migratory. Migratory movements might be correlated with weather conditions along the migration routes.

Local movements may be influenced by local weather conditions or disturbance factors such as fishing and pleasure boating. These latter factors become so important on the Bay that it is possible to place only limited interpretations upon population fluctuations within any one season. There seem to be, however, species differences in susceptibility to these disturbances. The diving ducks are apparently affected to a greater extent than the Mallard, Black Duck or Coot. I do not believe these disturbance factors are nearly so important on the "three lakes" where major population fluctuations are probably due largely to the arrival and departure of migrants. The possible effects of weather on migratory movements will be presented later. I will now attempt to point out some general relationships between the waterfowl populations of the "three lakes" and University Bay using Figures 9A, B and C.

In previous statements I have referred to the waterfowl "populations" of the "three lakes" and the Bay largely as a matter of convenience. Actually, I do not believe they constitute separate populations, at least in the sense that they migrate independently of one another. I can visualize the waterfowl relationship between University Bay and Lake Mendota as being represented by a one-fingered glove into which pebbles of two different sizes are poured. The smaller pebbles will first occupy the finger slot and then the body of the glove. The larger pebbles will occupy the finger slot only under pressure. Individuals of a flight of waterfowl arriving in the Madison area would seek resting sites according to their ecological preferences, perhaps through a process of random searching, or as influenced by the presence of local post-breeding populations. Such a "resident group" has been described for University Bay. I have no information concerning similar groups on lakes Waubesa and Kegonsa but, considering the development of their shorelines, I would not expect breeding waterfowl to be as numerous there as within the University Bay Game Refuge.

Under these conditions it would be expected that dabbling ducks would attain maximum numbers on University Bay before such numbers were attained on the "three lakes", while just the opposite would be true of the diving ducks. This is, in general, true. The four-year average chronologies (Figures 9A, B and C) show that Mallards and Black Ducks and other dabbling ducks reach maximum or nearly maximum numbers on the Bay several weeks before they reach such numbers on the "three lakes". Scaup sp., Canvasback and other diving ducks, on the other hand, attain maximum numbers first on the "three lakes" and then on the Bay. The limitations in locating "three lakes" migration peaks make precise yearly comparisons impossible. The early peak in Scaup sp. on University Bay (Figure 9B, October 16–22) is the result of 493 being recorded

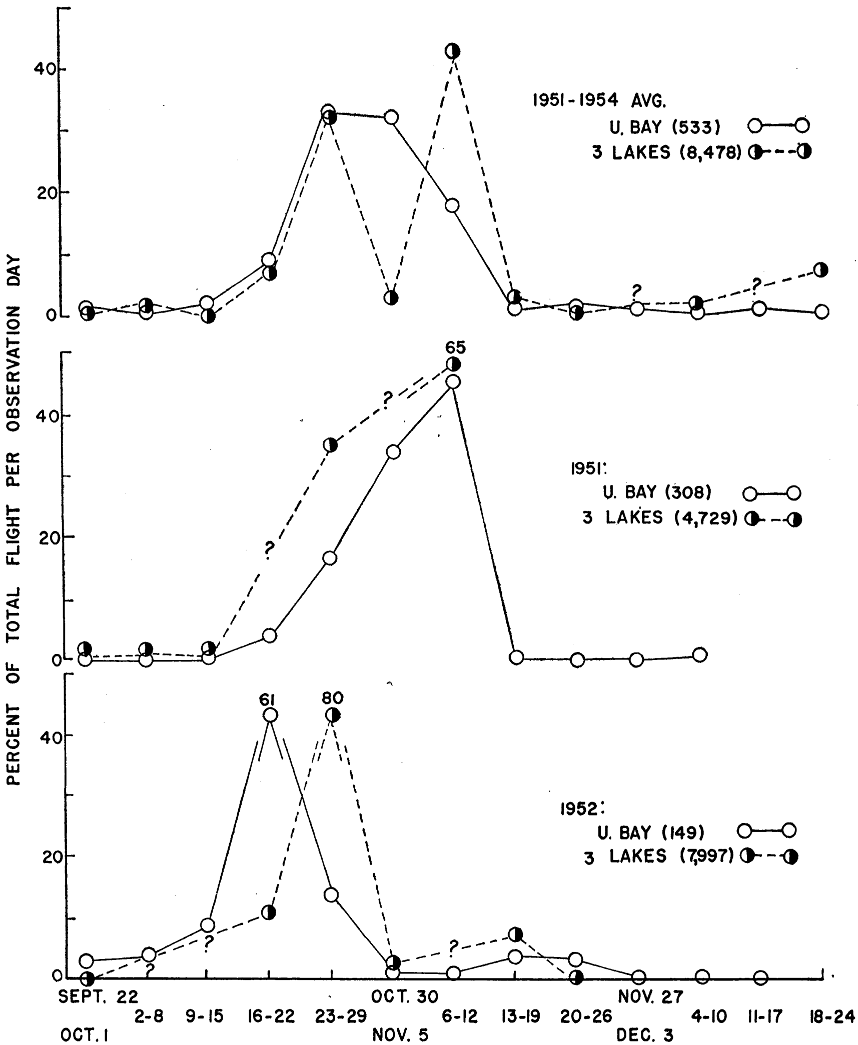

FIGURE 10A. Chronology of the fall migration of the Ring-necked Duck through University Bay and three Madison-area lakes (Mendota, Waubesa and Kegonsa). The total flight per observation day is given in parentheses.

during this period in 1954. The largest number of Scaup tallied during this week in any of the other three years was twenty-five. The late-season peak of Canvas-back on the Bay (Figure 9C, December 11–17) has been discussed previously. The Ring-necked Duck, although classified as a diving duck, fits into this picture of segregation upon arrival more as a dabbling duck. This is shown in Figures 10A and B where we see that maximum numbers are usually attained first on the Bay and then on the "three lakes." This is not surprising considering the many ecological characteristics linking the Ring-necked Duck with the dabbling ducks. The Coot does not conform to either pattern outlined above. Its average chronology curve (Figure 9A) indicates that population maxima

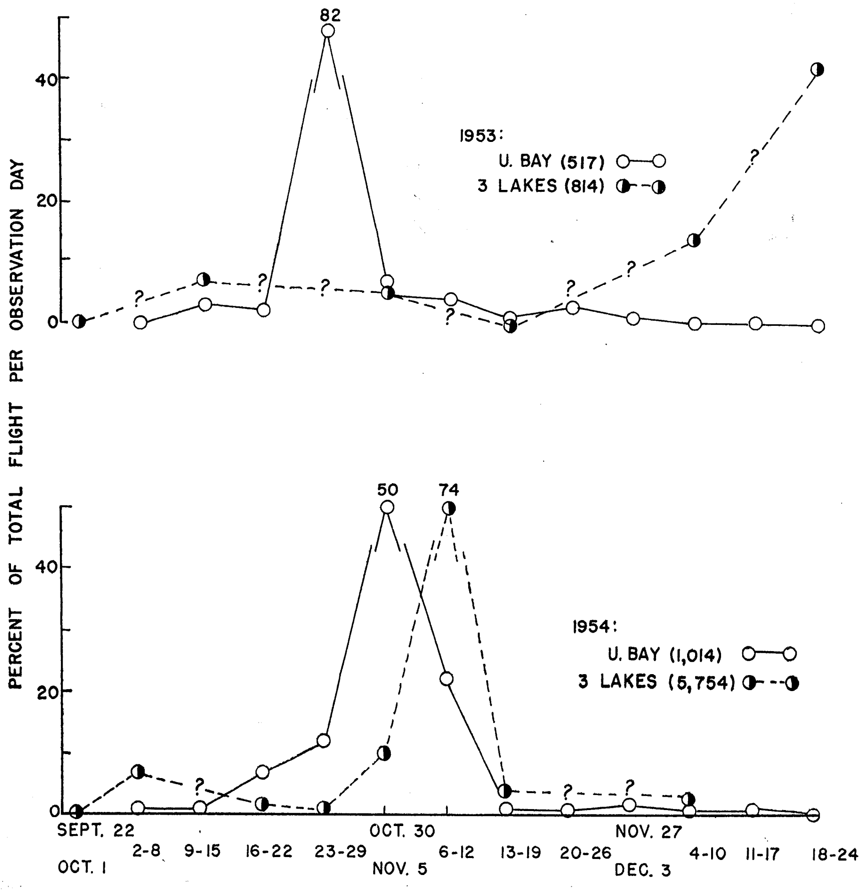

FIGURE 10B.

are reached at about the same time on the "three lakes" and the Bay. Actually there seems to be no set pattern. High populations may be attained first on the Bay and then the lakes or vice-versa (Figures 11A and B). This is not surprising since the Coot can feed successfully in the open waters of the lakes or in the shallower bays.

The tendency for the Mallard and Black Duck to maintain high population levels on the Bay while their numbers are still increasing on the "three lakes" (Figure 9A) suggests the operation of some mechanism which limits the numbers of these species on the Bay. Otherwise, why do not the Mallards and Black Ducks continue to increase on the Bay until food supplies are exhausted or, more

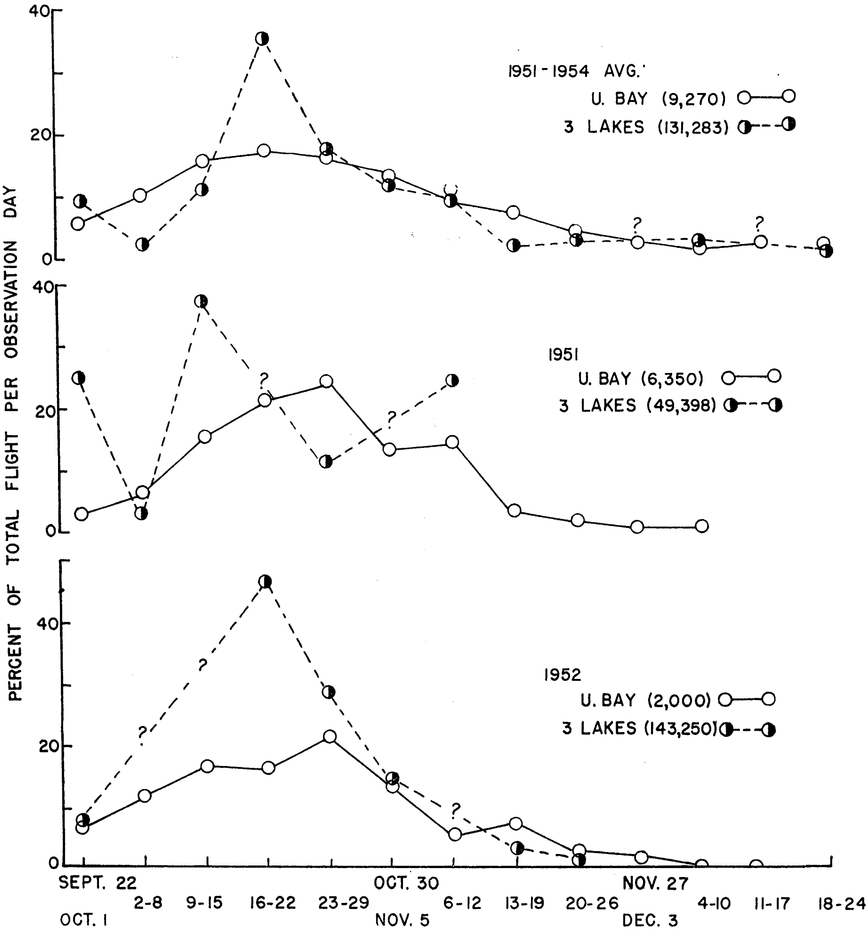

FIGURE 11A. Chronology of the fall migration of the Coot through University Bay and three Madison-area lakes (Mendota, Waubesa and Kegonsa). The total flight per observation day is given in parentheses.

to the point, why do they not continue to increase until there are no more new arrivals to swell their ranks, since they are making use of a food supply that is renewed each time manure is spread on the nearby cornfield? Actually there is little numerical evidence that "capacity" numbers of these species have been reached on the Bay during this study. This is indicated by the considerable annual variation shown in Table 3. A cumulative total 13,057 Mallards and Black Ducks used the Bay in 1953. This is considerably more than used the Bay during any of the other eight falls with the exception of 1949 when 12,530 were tallied. The increase in this case is slightly less than 4 per cent which indicates that the 1953 Mallard and Black Duck population may have approached "capacity" numbers on the Bay. Perhaps there are other factors that keep this population below that dictated by available food supplies. These

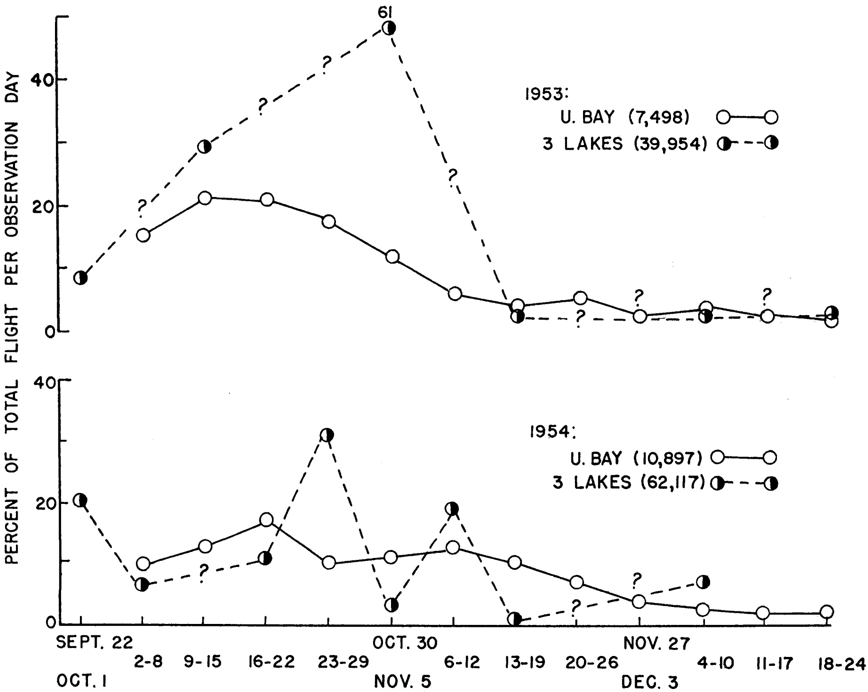

FIGURE 11B.

could be various physical features of the area or, perhaps, some aspects of human activity. Finally, the food supply may be the limiting factor, but this seems unlikely since considerable corn is supplied them both through harvest waste and the periodic spreading of manure as fertilizer.

The relationship between the average hunting season for 1951 through 1954 (October 5–November 26) and the average waterfowl flight through University Bay and the "three lakes" for the same period is shown in Figures 9A, B and C. In general, the span of the hunting season has included the periods of high population numbers of most of the species involved. Exceptions would be late migrants such as the Buffle-head and American Golden-eye as well as occasional late flights of other diving ducks. More important, however, is the indication that the harvest of the Mallard could be increased by allowing more shooting days in late November. Wisconsin waterfowl kill statistics for 1954 (Jahn, 1955) show that the Mallard is certainly one of the most important if not *the* most important species to Wisconsin duck hunters.

Many phenomena have been correlated with bird migration both spring and fall. For example: the photoperiod (Rowan, 1946), food supply (Rowan, 1947), temperature (Lincoln, 1950), barometric pressure (Dennis, 1954) and fat deposition and pituitary activity (Wolfson, 1945). Farner (1950) concludes that bird migration has a "multiple origin": the "disposition to migrate" involves a number of physiological mechanisms that may or may not be triggered by the external environment. In view of the diverse correlations mentioned above, Farner's stand seems to be a logical one to take at this time.

Much evidence has been gathered linking bird migration to rising temperatures in the spring (Lincoln, *op. cit.;* Cooke, 1913; Dennis, *op. cit.*) and the movement of cold fronts in the fall (Bennett, 1952), so that it now appears probable that temperature actually exerts a "triggering" influence. Acting upon this assumption, I have presented the chronology of the fall waterfowl flight through the "three lakes" and University Bay for 1951, 1952, 1953 and 1954 together with daily minimum temperature calculated as two-day-average deviations from the monthly mean minimum temperature (Figures 12A, B, C and D). Curves are shown for all dabbling ducks and all diving ducks, excluding the Canvas-back. Canvas-backs are excluded because, in all years except 1954, they were present on the Bay in too few numbers per observation day to allow the construction of a meaningful curve. The abnormalities of the 1954 fall Canvas-back flight through the Bay have already been discussed. Since this species could not be included in the University Bay curves, I excluded it also from the "three lakes" curves.

Daily minimum temperature records were obtained from the U. S. Department of Commerce Weather Station at North Hall on the campus of the University of Wisconsin. In the spring of 1953 this station was moved to Truax Airport a few miles east of its former location. In addition, I consulted daily weather charts of the United States and southern Canada published by the U. S. Department of Commerce Weather Bureau, Washington, D. C. The purpose of these investigations was to explore any obvious correlations between the fall migration of waterfowl through the Madison area and weather conditions from the origin of the migratory

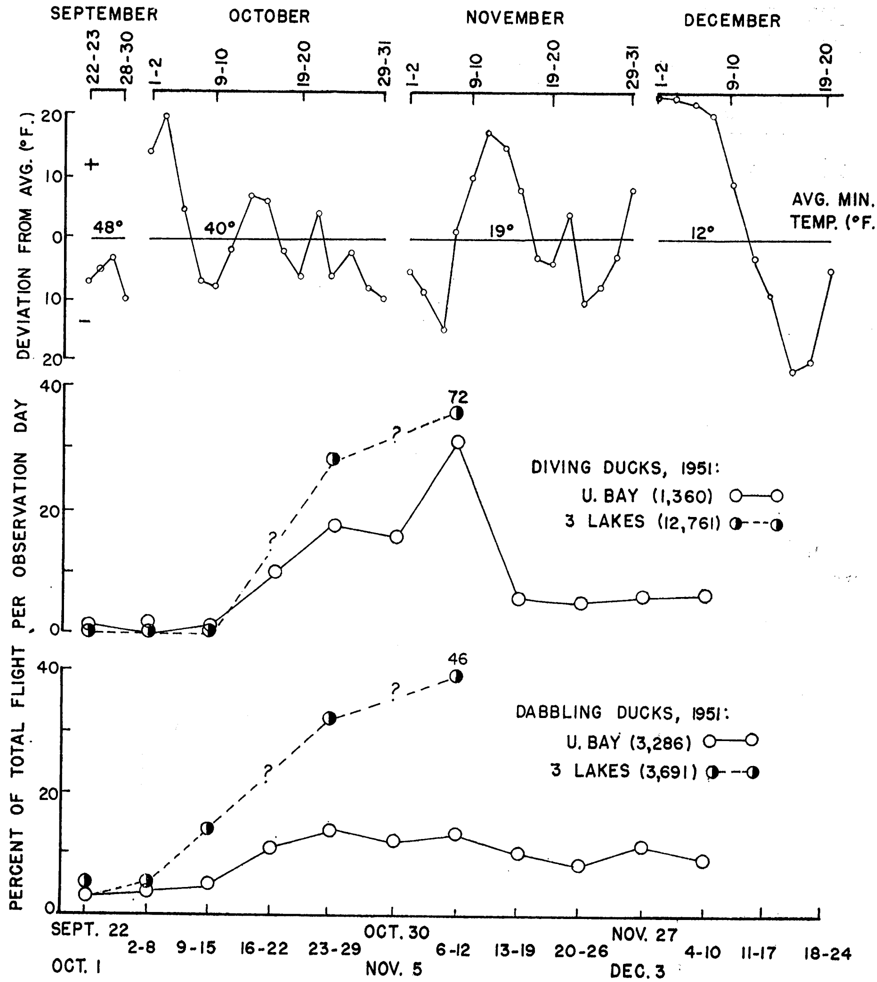

FIGURE 12A. Chronology of the fall migration of dabbling and diving ducks (excluding Canvas-back) through University Bay and three Madison-area lakes (Mendota, Waubesa and Kegonsa) in relation to daily minimum temperature at Madison (shown as two-day-average deviations from the mean monthly minimum temperature). The total flight per observation day is given in parentheses.

flights, presumably the breeding and molting grounds of the species involved, to the lakes of south-central Wisconsin.

The breeding and molting grounds of the majority of the waterfowl passing through the Madison area in fall migration are in the prairie provinces of Canada: Alberta, Saskatchewan and Manitoba (Aldrich *et al*, 1949). Exceptions to this would be the Black Duck, Buffle-head, American Golden-eye and Ring-necked Duck which breed either farther north or to the east. Because of the physiographic configuration of the state therein and distribution of wetlands (Mann *et al.* 1955), these ducks migrate into south-central

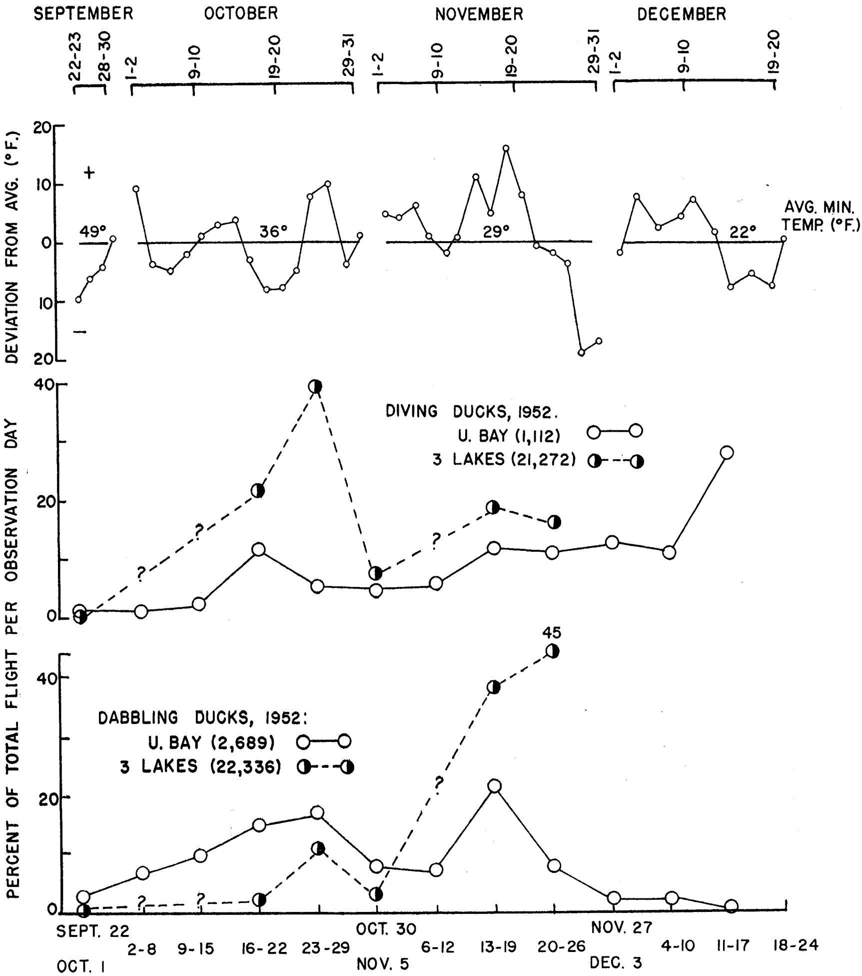

FIGURE 12B.

Wisconsin from the northeast. Nevertheless, it is the movement of storms, cold fronts and freezing temperatures from the northwest across western Canada that brings these migrants to the Madison area (assuming weather to be responsible).

An examination of Figures 12A, B, C and D shows that in nearly every instance major peaks of waterfowl numbers were attained

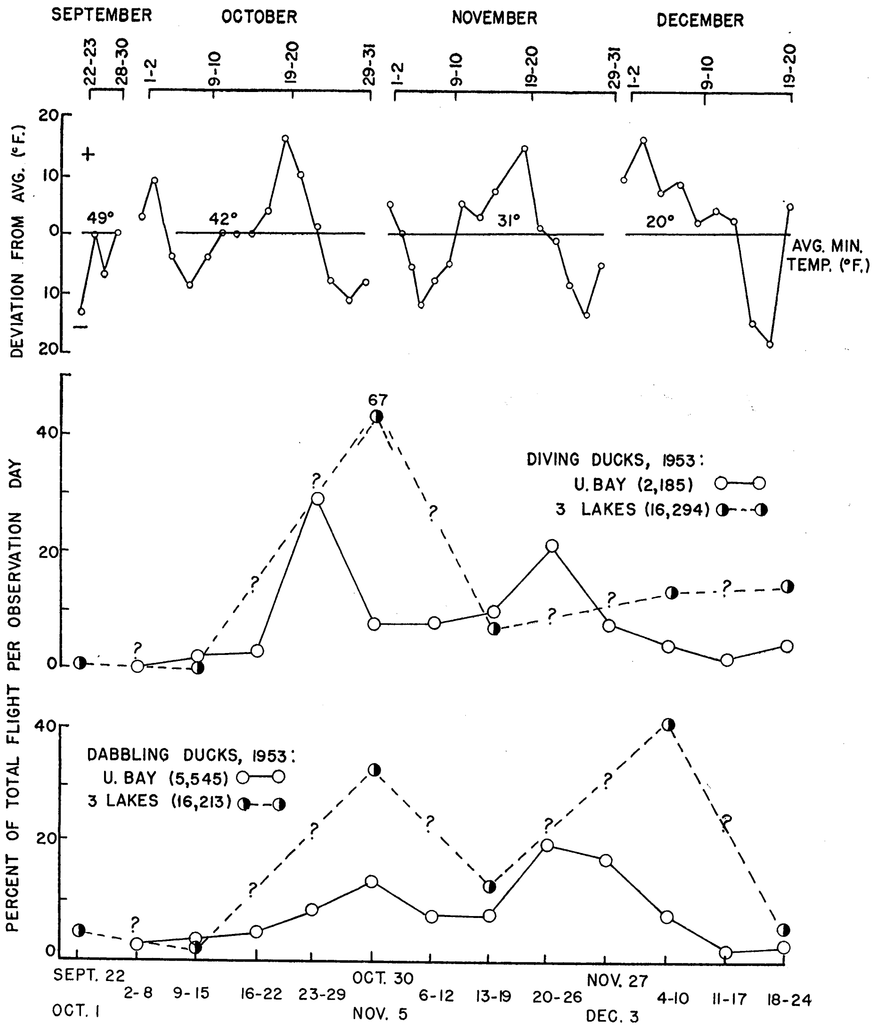

FIGURE 12C.

on the "three lakes" and the Bay either during or immediately after sharp declines in local minimum temperature. Thus in 1951 (Figure 12A) high numbers of both dabbling and diving ducks were either reached or were being rapidly approached during the week of November 6–12. This was immediately after a period in which the daily minimum temperature dropped from 30° to 4° F. On University Bay, dabbling ducks attained maximum numbers some two weeks before this when daily minimum temperatures were dropping from 44° to 30° F. A similar situation occurred in

1953 (Figure 12C) when diving ducks reached their highest population levels on the Bay during the week of October 23–29. At this time daily minima were dropping from 43° to 31° F. Dabbling duck populations peaked from November 20–26 as daily minimum temperatures decreased from 46° to 17° F.

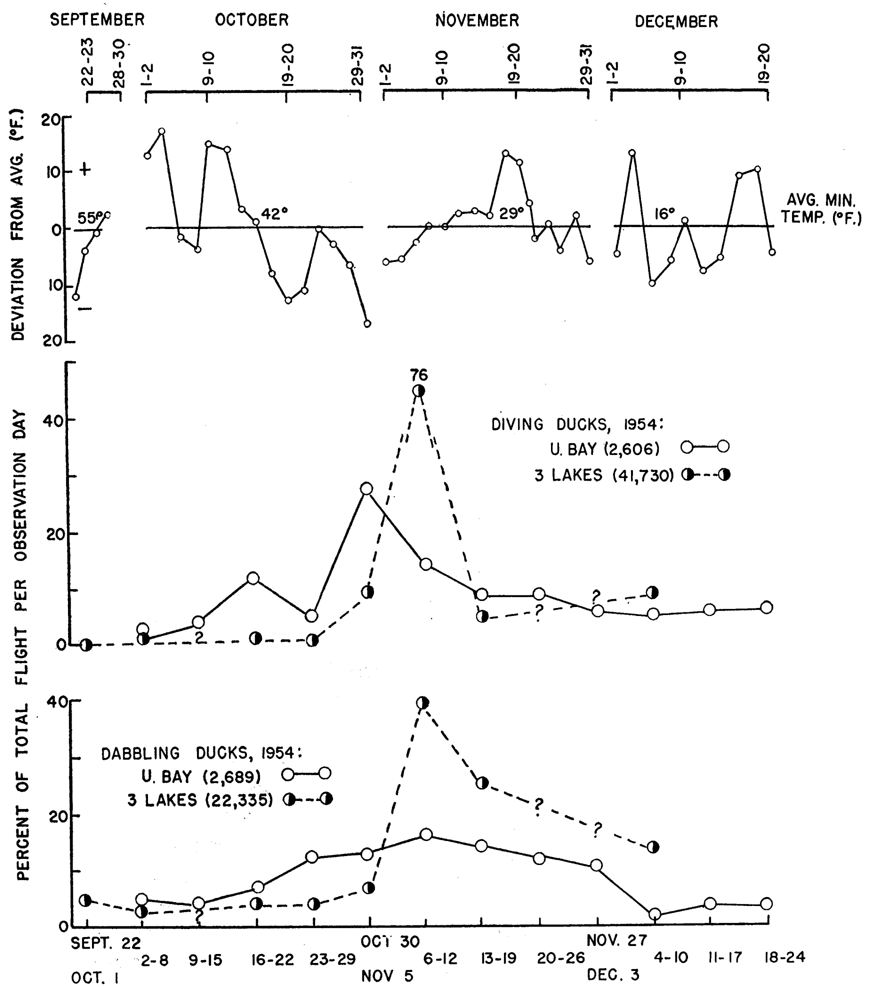

FIGURE 12D.

Other examples could be cited from any of the four years involved, some not so striking, perhaps, as the two given, but all indicating a definite correlation between the arrival of waterfowl flights in the Madison area and periods of decreasing local minimum temperature.

My examination of daily weather charts revealed a similar correlation between these flights and the movement of cold fronts, followed by freezing temperatures, across western Canada and into the Midwest. This agrees with the findings of Bennett (*op. cit.*) who studied the fall migration of birds through the Chicago area from 1946 through 1950. Bennett, however, found a correlation between the arrival of migration waves and "strong NW to N winds" in association with the cold fronts. I found no obvious correlation of this nature. The arrival of Mallards and Black Ducks in the Madison area was frequently associated with the presence of storm tracts moving east across southern Canada or into the Midwest from the Southwest. These storms were usually associated with low pressure areas, freezing temperatures and rain.

University Bay as a Refuge

In the preceding sections of this paper I have attempted to describe the University Bay Game Refuge and to show how and when it is used by waterfowl. I have further shown what species of waterfowl may be expected and in what numbers. It now remains to comment upon the effectiveness of this area as a local waterfowl refuge.

Leopold (1933) has defined a game refuge as ". . . an area closed to hunting in order that its excess population may flow out and restock surrounding areas." According to Wisconsin Conservation Commission Order Gr-520, Rev. 2, this is essentially the purpose for which the University Bay Game Refuge was established. The question is, then, to what extent is this refuge fulfilling its purpose? It has been shown that most species of waterfowl using the Bay usually attain high population levels there during the hunting season (Figures 3 and 9A, B and C). It is impossible to tell to what degree these ducks "restock surrounding areas" without making use of some method of marking and noting their recovery in hunters' bags. There are, however, other criteria which may be used to evaluate the usefulness of the area.

In discussing the management of small areas as waterfowl refuges, Pirnie (1940) has established the following objectives:

1) Aids to Birds (food and protection).
   a) loafing and refuge from hunting.
   b) safe feeding and special feeds.
2) Benefits to Humans (education and recreation).

These objectives stem largely from Pirnie's work at Wintergreen Lake sanctuary near Battle Creek, Michigan, which contains thirty acres of water and six hundred acres of woodlot and fields. Since it is near a larger body of water, it has many physical characteristics similar to the University Bay Refuge.

The Bay refuge possesses most of the above mentioned criteria. It offers adequate loafing spots at the mouth of University Creek and at the drainage inlet. There is complete protection from shooting within the refuge boundaries. The ducks can feed safely on the Bay or in the nearby cornfield. The periodic spreading of manure provides special feed to those species that stubble feed. The waterfowl using the Bay have access to larger bodies of water which Pirnie (*op. cit.*) considers almost as important a consideration as food. These "landing fields" provide food and rest for the waterfowl when they leave the refuge. What the University Bay refuge does not provide is protection from disturbance other than hunting. Traffic on University Bay Drive is heavy. Cars park in lots along its length from which people watch the activities on the Bay. Fishermen use the Bay well into November. A bathing beach at the south end of the gravel bar is open to the public until late September. The outing facilities on Picnic Point are used by numerous students and townsfolk. The varsity crew even makes use of the outer Bay in rowing drills. In this respect, the area is more like a park than a refuge. The main disturbance to the waterfowl, however, is caused by fishermen, many of whom persistently use the Bay until late November and, as I have mentioned earlier, it is the diving duck segment of the waterfowl population that is most susceptible to these disturbances.

Bellrose (1954) has discussed the relationship between the size of a refuge and its effectiveness. He has shown that, where hunting is allowed up to the refuge boundary, the larger areas are usually more effective in holding waterfowl than smaller ones. However, where the surrounding land is closed to hunting, small areas can be important, as for example, 314-acre McGinnis slough just outside of Chicago. He also states that protected ponds as small as thirty acres have attracted and held several thousand Mallards. Bellrose (*ibid.*) has pointed out that small refuges can be more valuable per unit of area than large ones because of the ability of ducks (primarily Mallards and Black Ducks) to feed over a much greater area than that covered by the refuge itself. Band returns have shown this "feeding radius" to be about twenty-five or thirty miles. I do not believe this phenomenon greatly increases the effectiveness of the University Bay refuge for here the Mallards and Black Ducks stubble feed on the refuge itself.

The Bay and human activity has been discussed thus far only from a negative point of view. There is, however, an important positive aspect which will have considerable bearing upon future Bay-use policy. Salyer (1945) has stated that one of the most important permanent values of a refuge is its function as a field laboratory. While it is not a field laboratory for experimental waterfowl research, the Bay is certainly important to the University of Wisconsin. Studies I have referred to in the first sections of this paper have shown its contributions to limnological research. Besides using the Bay as a site for a project in wildlife management techniques, the Department of Forestry and Wildlife Management makes use of the refuge area for field research and various class exercises. The Bay provides a field demonstration in the growth of aquatic plant communities useful to the Botany Department, as well as being a source of laboratory material. A number of zoology classes visit the area. For example, it is the site of a spring project similar to the one upon which this paper is based; it is ideally located for ornithology field trips and is also used for mammalogy demonstrations and field exercises. Classes in elementary zoology and integrated liberal studies make field trips to the area. It is also a source of zoology laboratory material and provides a unique field demonstration for classes in ecology, since the Bay contains one of the few marsh remnants on the lake. Its north and south shores, being protected and unprotected from wave action respectively, also provide interesting ecological comparisons.

Limited use is also made of the Bay by Madison civic groups. It is a regular observation area of the Madison Audubon Society on their annual Christmas and May-day bird counts. Boy scouts have also visited the area in fulfilling various merit badge requirements.

All of these uses must be considered in formulating an integrated plan for the future use of University Bay and the refuge land around it. The land belongs to the University of Wisconsin which is feeling the pinch of expansion. If the Bay is to be preserved, therefore, academic values must be stressed. For this reason I do not believe its full potentialities as a waterfowl refuge will ever be realized, but its use as an outdoor area by the University and the city of Madison is increasing each year.

Acknowledgments

I would like to acknowledge the assistance of Albert Gallistel and staff of the University of Wisconsin Office of Physical Plant Planning for information concerning the acquisition of land around University Bay, of F. W. Duffee of the Department of Agricultural Engineering for facts dealing with land use and development, and of A. C. Breitenbach of Madison for details concerning the history of hunting and trapping on the Bay.

J. R. Smith and L. R. Jahn of the Wisconsin Conservation Department contributed data on the establishment of the University Bay Game Refuge and waterfowl populations on the "three lakes" respectively, for which I am grateful.

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SUMMARY

The purpose of this paper is an evaluation of University Bay as a local waterfowl refuge through a consolidation and evaluation of nine-years' observations on fall waterfowl migration.

Observations were made every 2.6 days over an 80-day average annual observation period extending from September 29 through December 17 for the nine years 1946–1954. Additional data gathered by aerial surveys over Lakes Mendota, Kegonsa and Waubesa were contributed by the Wisconsin Conservation Department. These surveys were conducted once every 9.4 days over a 66-day average annual observation period extending from September 25 through November 29 for the years 1951–1954, inclusive.

Twenty-three species of waterfowl were seen on the Bay at some time during the field periods of this study. Of these, 11 species were considered "common." These were: Mallard, Black Duck, Baldpate, Gadwall, Shoveller, Ring-necked Duck, Scaup sp., Canvas-back, Buffle-head, American Golden-eye and Coot.

A cumulative total of 258,506 ducks and Coots was recorded on the Bay during this study. This represents a rate of use of the 180-acre body of water of approximately 360 ducks and Coots per day of the average annual observation period per year. The Coot was the most numerous species on the Bay representing about 56 per cent of the total.

Population data indicate a trend toward an annual increase in the number of waterfowl using the Bay. The average annual rate of increase for the nine years was 29 per cent. This trend was also evident in the aerial survey data. An examination of Audubon Field Notes fall migration records and U. S. Fish and Wildlife Service data indicates that these increases may be due to actual increases in the Mississippi Flyway waterfowl population. There is also some evidence that they may be due to local ecological changes of a temporary nature.

Chronologically, at least five species of waterfowl are represented on the Bay throughout the average annual observation period. The greater number are present from mid-October to late November during which time most species attain maximum numbers. The most persistent users of the Bay are Mallards and Black Ducks. They exhibit what is apparently an extended migration period with high population levels maintained for about six weeks. Indications are that individuals of these species remain on the Bay, taking advantage of the opportunity to stubble feed in a nearby cornfield, instead of leaving after a short stay. Diving ducks are not as well represented numerically on the Bay as are the dabbling ducks. They are apparently more susceptible to disturbance factors.

In general, dabbling ducks attain maximum population numbers on the Bay before they do on the "three lakes." The opposite is usually true of diving ducks. This is most consistently demonstrated in the Mallard and Black Duck, which suggests the operation of a mechanism that limits the "carrying capacity" of the Bay for these species. The limiting factor(s) is (are) not known. There is little evidence, however, that the Bay could not have held more individuals of these species during any year of this study.

Aerial and ground survey data show that the Wisconsin waterfowl season has usually embraced the periods of maximum waterfowl populations in the Madison area. Possible exceptions are the Buffle-head, American Golden-eye and occasional late flights of other diving ducks. There is also the indication that additional hunting days in November might increase the local harvest of Mallards and Black Ducks.

A correlation apparently exists between the chronology of the fall waterfowl flight through the Madison area and fluctuations in local daily minimum temperature. Population increases were noted during or immediately after periods of decreasing minimum temperatures. An examination of daily weather maps showed a similar correlation between the movement of migrant waterfowl into the Madison area and the progress of cold fronts, freezing temperatures and storm tracts across southern Canada and into the Midwest.

The University Bay refuge fulfills most of the physical and functional requirements of a refuge. It is, however, subjected to such intense use by University and civic interests in academic and recreational activities that its maximum potentialities as a waterfowl refuge will probably never be realized. This is in keeping with the necessity of putting the area to its greatest *overall* use.

APPENDIX A

SCIENTIFIC AND COMMON NAMES OF WATERFOWL MENTIONED IN TEXT

Family *Anatidae*

Subfamily *Anserinae*

Tribe *Anserini*

Branta canadensis, Canada Goose
Anser caerulescens, Blue Goose, Snow Goose
Cygnus columbianus, Whistling Swan

Subfamily *Anatinae*

Tribe *Anatini*

Anas acuta, Pintail
Anas crecca, Green-winged Teal
Anas rubripes, Black Duck
Anas platyrhyncos, Mallard
Anas strepera, Gadwall
Anas americana, Baldpate
Anas discors, Blue-winged Teal
Anas clypeata, Shoveller

Tribe *Aythyini*

Aythya valisineria, Canvas-back
Aythya americana, Redhead
Aythya collaris, Ring-necked Duck
Aythya affinis, Lesser Scaup
Aythya marila, Greater Scaup

Tribe *Cairinini*

Aix sponsa, Wood Duck

Tribe *Mergini*

Melanitta nigra, American Scoter
Melanitta perspicillata, Surf Scoter
Melanitta fusca, White-winged Scoter
Clangula hyemalis, Old-squaw
Bucephala clangula, American Golden-eye

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Bucephala albeola, Buffle-head
Mergus cucullatus, Hooded Merganser

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Heteranthea dubia, mud plantain
Lemna sp., duckweed
Myriophyllum exalbescens, water milfoil
Najas flexilis, bushy pondweed
Nelumbo lutea, American lotus
Nymphaea tuberosa, white water lily
Phelum sp., timothy
Poa compressa, wiregrass
Potamogeton americanus (nodosus), knotty pondweed
P. amplifolius (ilinoensis)
P. angustifolius, large-leaf pondweed
P. crispus, curly-leafed pondweed
P. natans, floating brownleaf
P. pectinatus, sago pondweed
P. praelongus, whitestem pondweed
P. Richardsonii, clasping-leaf pondweed
P. zosteriformis, flat-stem pondweed
Ranunculus sp., crowfoot
Salix sp., willow
Scirpus acutus, hard-stem bulrush
Sparganium sp., bur reed
Typha sp., cattail
Utricularia vulgaris, bladderwort
Vallisneria americana (spiralis), wild celery
Zannichella palustris, horned pondweed
Zea mays, corn

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AN UNPUBLISHED MANUSCRIPT OF E. A. BIRGE ON THE TEMPERATURE OF LAKE MENDOTA; PART II[1]

JOHN C. NEESS and WILLIAM W. BUNGE, JR.
Departments of Zoology and Geography, University of Wisconsin

SURFACE MAXIMA (1916)

The temperature observations have been taken with reference to ascertaining the maximum temperature of the lake rather than that of the surface. They have, therefore, been taken commonly later in the day than the hour of maximum surface temperature.

The highest temperature recorded is 34.3° on July 29, 1916, 1:45 p.m. It is hardly probable that a temperature essentially higher has ever been present in the lake. This was the highest of a series taken during a perfectly calm afternoon at the close of a long hot period. The maximum air temperature on that day was 38.5°, while the maximum air temperature recorded in 57 years is 40.0°. The sun shone until 4:15 p.m. and the surface at another station at 4:30 read 33.4°. In taking these readings the bulb of a standard thermometer was laid horizontally just below the surface. Under the conditions of sun, air and wind, the temperature recorded depends on the thickness of the stratum of water affecting the instrument. The recorded temperature is that of a stratum about 1 cm. thick. Doubtless the upper half of that stratum was decidedly warmer than the record. A Negretti and Zambra thermometer, whose bulb extended 5–7 cm. below the surface, gave a reading of 33.0° instead of 34.3°.

Other high readings taken with the Negretti and Zambra thermometer are as follows:

27.6°,	1909,	June 30,	12:00 noon
32.1 ,	1910,	June 30,	4:00 p.m.
29.0 ,	1911,	June 23,	4:30 p.m.
27.6 ,	1912,	June 29,	2:15 p.m.
29.9 ,	1913,	June 29,	3:30 p.m.
28.8 ,	1914,	July 11,	3:00 p.m.

Very probably a reading as high as that of 1916 could have been found in 1910, and possibly in 1913. In no other year of the list, however, is it probable that the surface would have registered above 30.0° if read with a Negretti and Zambra thermometer.

[1] Continued from Volume 45.

During nine years it is possible to state the number of days on which the surface rose above 25.0°. In 1915 this temperature was not reached at all. In 1916 the surface remained above 25.0° from July 10 to August 12, 33 days, by far the longest period on record. It is possible, though hardly probable, that in the early hours of certain mornings in this period the surface fell a little below 25.0°.

The numbers of days on which the surface reached 25.0° in the various months are given here:

	Average	*Maximum*	*Year of Maximum*
June	3.1	10	1910, 1911
July	15.0	24	1916
August	5.6	18	1916
September	0.4	2	1912

In each case the minimum number of days is zero. Probably a longer series would give a higher maximum number of days to September. The surface reached 25.0° in only two years of the nine.

Diurnal Variations of Surface Temperature (1916)

Temperature observations were taken twice a day during most of the open season of three years: 1897, 1898, 1911. The observations were made early in the morning, usually about six o'clock, and in the late afternoon, 4–6 o'clock. The morning observations would be close to the minimum, but the afternoon observations would often be too late for the maximum. The daily range of temperature based on these readings, therefore, would tend to be too small. Yet as the days on which observations were missed would be the stormy and cold days, during which the surface would fall during the day, and as all the calm days of maximum change would be included, the mean is probably not far wrong.

It is also true that the maximum surface temperature depends very largely on the wind. If the day is calm and bright the maximum may persist until near sunset. On numerous occasions in 1911, 1912, and 1913, when readings were made at some ten stations in the lake during the afternoon, the late afternoon readings were as high or higher than those made earlier, if the afternoon was calm. If there was a breeze, there was little change as the hours passed. A change from calm to breeze causes an instant and considerable decline of temperature, even if the breeze is very light. Such a change, for example, caused a fall in the surface from 26.5° to 24.8° between 4:30 and 5:45 p.m. on September 13, 1897. The following table shows the results of the observations in the several years,

TABLE III–2

DIURNAL CHANGES OF SURFACE TEMPERATURE

(Differences between Morning and Afternoon Readings), 1897, 1898 and 1911

Month	Cases		Mean Change	Maximum Change	Minimum Change
May	50	Day	+1.34°	+6.8	—1.6
		Night	—0.89	—5.7	+1.0
June	65	Day	+1.26	+6.5	—0.5
		Night	—1.16	—6.7	+0.8
July	86	Day	+0.81	+3.7	—1.0
		Night	—0.81	—4.0	+0.6
August	82	Day	+0.76	+3.2	—0.6
		Night	—0.81	—2.8	+0.8
September	85	Day	+0.54	+2.7	—1.8
		Night	—0.81	—2.0	+0.4

There is little use in trying to establish a mean daily variation of the surface for April or early May, unless simultaneous observations can be taken at several points of the lake so as to secure a mean for each observation. The temperature at the center of the lake varies with the changes in direction and velocity of wind far more than it does later in the season when the epilimnion has been formed. Thus on April 27, 1911, the temperature in the limnetic region ranged at six stations from 6.6° to 10.3°. A shift of wind might easily have caused the surface at the first station to indicate a rise of 3.0°, or more, during the night. On April 19, 1913, the range was from 5.6° to 6.8° in deep water, rising to 8.3° in water 2–5 m. deep.

Similar, though less marked, differences may be found on any calm day in summer. Local breezes disturb the surface at one place and leave it calm in another, and considerable differences are thus occasioned. But these affect the water to a very slight depth. In the spring many of these differences are due to relatively large masses of water transported by the wind. Vertical stratification is still weak and the warm water may be on one side of the lake and the cooler water on the other. Under such conditions there may be accumulated a huge mass of warm water to be spread over the lake when the wind falls or changes. Such conditions are impossible after the thermocline is fairly established.

Diurnal variations of surface are not noted after October 1. During October, 1897 and 1898, pairs of observations were made on 45 days, showing an average rise of 0.16° during the day and a fall of 0.34° during the night. Inclusion of all the days would have shown a much smaller rise by day and a greater fall by night. After mid-October the days are few and exceptional when the passage of the day shows any observable rise of temperature of the lake's surface.

Depth of Penetration of Surface Temperature (1916)

No accurate measurement can be made of the depth to which the lake cools by night or warms by day. The wind has so much effect as to obscure other causes unless a very long series of observations can be used. If observations are made every morning and afternoon there is, however, no difficulty in stating the depth at which the surface temperature in the morning lay on the preceding afternoon, or, by comparing the morning and afternoon observations of the same day, to ascertain the depth to which the surface temperature of the morning has moved down during the day. This distance, however, does not necessarily mean the depth to which the lake has warmed or cooled, since oscillations of the water or currents may either increase or diminish this distance at the place of observation, quite independently of any change of temperature.

The following table (Table III–3) shows the facts for June, July and August during the years 1897, 1898 and 1911, in which observations were regularly made twice a day.

The mean of all cases, 240 for night and 241 for day, shows an apparent nocturnal cooling through 4.5 m. and an apparent diurnal warming through 4.1 m.

TABLE III–3

VERTICAL MOVEMENT OF SURFACE TEMPERATURE

Year	June				July				August			
	Morning		Afternoon		Morning		Afternoon		Morning		Afternoon	
	Cases	Depth	Cases	Depth	Cases	Depth	Cases	Depth	Cases	Depth	Cases	Depth
1897...	19	3.9 m.	21	5.6 m.	23	3.9 m.	28	3.5 m.	27	7.6 m.	27	4.5 m.
1898...	25	4.8	24	4.9	31	3.4	31	3.2	27	4.0	27	3.7
1911...	25	2.8	25	2.6	29	5.0	29	4.1	29	5.2	29	4.9
Mean..	69	3.8	70	4.4	88	4.2	88	3.7	83	5.6	83	4.4

The range of movement varies greatly. It is greatest in days or nights of much wind and small changes of temperature when a stratum 10–18 m. thick may apparently rise or fall 0.1–0.3 degrees. It is least in calm, hot weather when the range of movement may be only 1–3 m., and its thermal extent may be considerable. A month which shows a large movement, like August, 1917, has many cases of the first sort. One with a small mean movement, like June, 1911, has many cases of the second kind.

The above table is not to be interpreted as giving the zone within which the diurnal variations in temperature take place. Nor does it show the depth to which the sun's influence penetrates. It is not

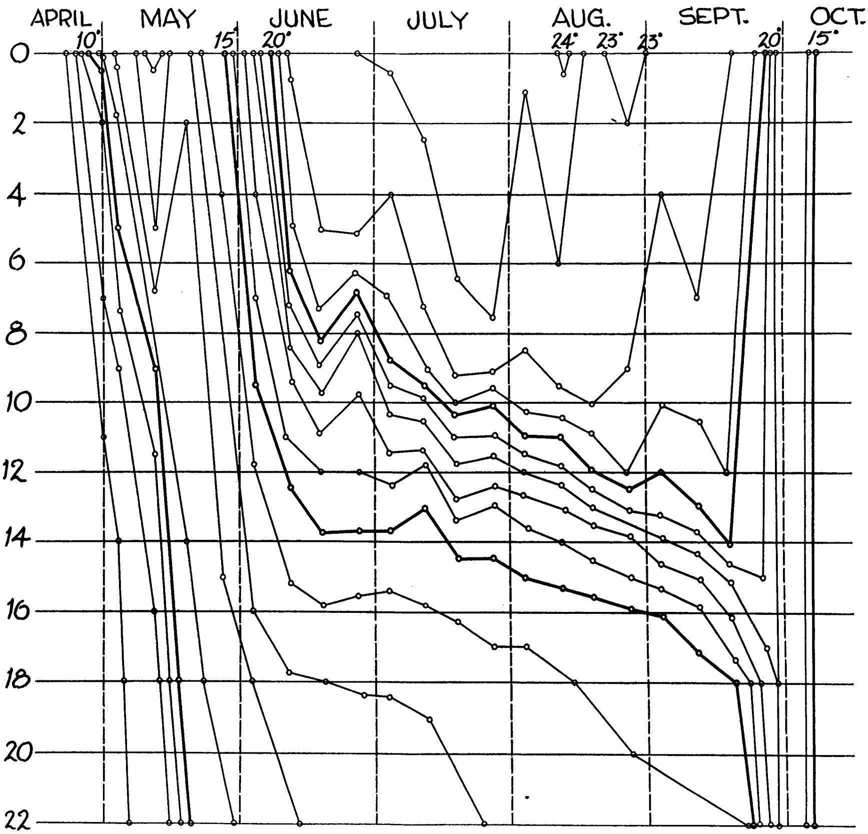

FIGURE 25. Distribution of temperature in Lake Mendota during the open season of 1895.

true either that the mean temperature curve for the morning observations would show a straight line to the depth indicated by the table. It shows only the facts stated, i.e., the mean diurnal movement of the surface temperature, downward during the day and upward during the night. Perhaps its chief value is to show that this movement has no relation either to the establishment of the thermocline or to the depth below the surface of the lake at which it lies.

THE SUMMER SEASON (1916)

It may be said in general that the summer conditions of Lake Mendota are established when the weekly mean of surface temperature rises to 20° and that they continue so long as the surface remains above 20°. If this period is taken from the diagrams (Figs. 9 through 22) its mean length from the observations of 13 years

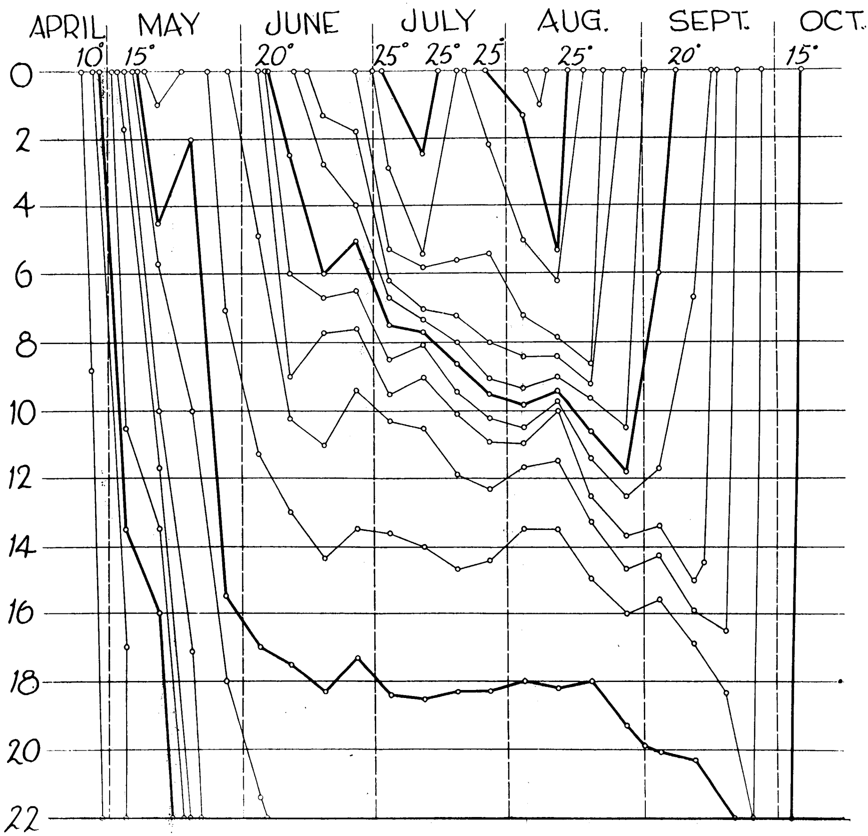

FIGURE 26. Distribution of temperature in Lake Mendota during the open season of 1896.

is 95 days, June 4 to September 17. The shortest period was 67 days in 1915, June 20 to August 26. In this year a cold wave in late August carried the surface temperature below 20.0°. But it remained between 19.5° and 20.0° until September 20, so that practically the summer conditions did not end till that date.

The longest period was 114 days in 1911, June 1 to September 21. This was also the earliest date for the surface to reach 20.0°. The latest date was July 8 in 1917, after a June and early July whose temperatures were as low as the lowest record.

The earliest date for recrossing of the 20.0° line was in 1915, as stated above; the latest, September 27, in 1895.

SUMMER TEMPERATURES AND THE THERMOCLINE (1899)

A direct stratification of temperature necessarily prevails, in general, in a lake during the open season from the time that the

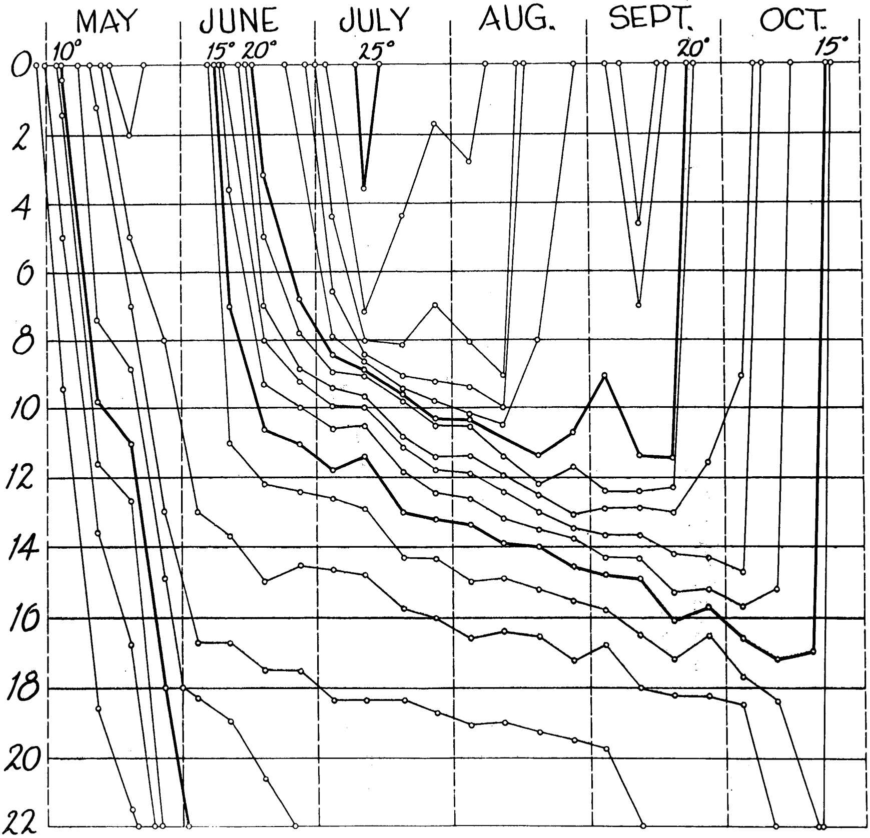

FIGURE 27. Distribution of temperature in Lake Mendota during the open season of 1897.

water has reached 4° in the spring until it has cooled to the same temperature in the autumn. The water of any given stratum has a higher temperature than the water of any stratum situated below it. The distribution of the fall of temperature through a column of water may, however, be either approximately equal or extremely unequal. The distribution depends upon several factors, among which may be mentioned: (1) the distribution of solar radiation, (2) the transparency of the water, (3) the effect of the wind as modified by the area, depth, and shape of the lake. In bodies of water which are large enough and deep enough to be called lakes, the direct action of the sun on strata below the immediate surface is so much less than that of the wind that its effects are almost

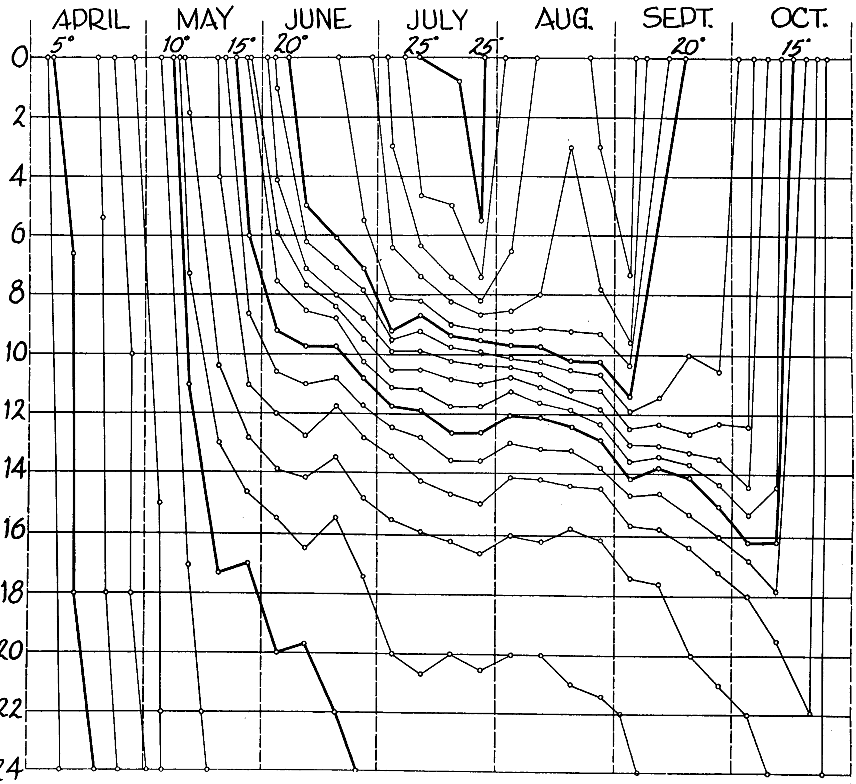

FIGURE 28. Distribution of temperature in Lake Mendota during the open season of 1898.

entirely obscured in the average of a number of readings extending over any considerable time.

The distribution of heat through the water is, therefore, primarily due to the action of the wind. It follows that in a lake like Mendota, which has a comparatively large area and small depth, the warmth received from the sun will ordinarily be rapidly distributed and to considerable depths, and that the temperature of the bottom water will follow that of the surface during the early spring. Examination of the diagrams showing the movement of the temperature during the open seasons of 1895 through 1898 (Figs. 25, 26, 27 and 28) and of those showing weekly temperature averages for the four years (Figs. 29 and 30) plainly discloses this fact. In the diagram in Fig. 30 (1898) the bottom temperature closely follows that of the surface through April and the first week in May. At that time the surface had reached a weekly average of

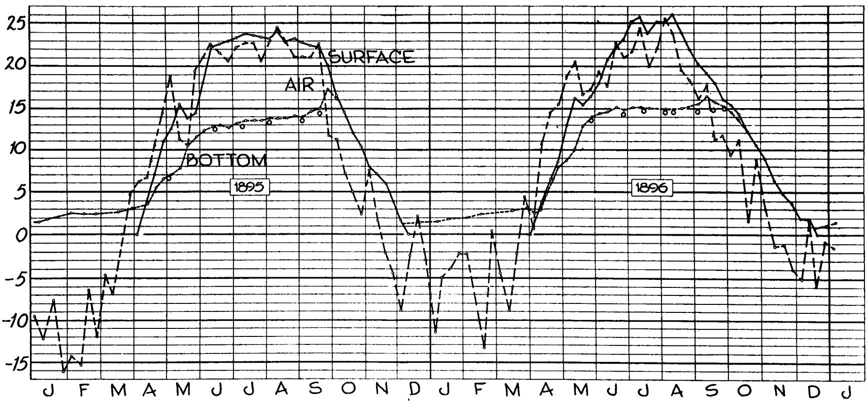

FIGURE 29. Temperatures in Lake Mendota during 1895 and 1896.

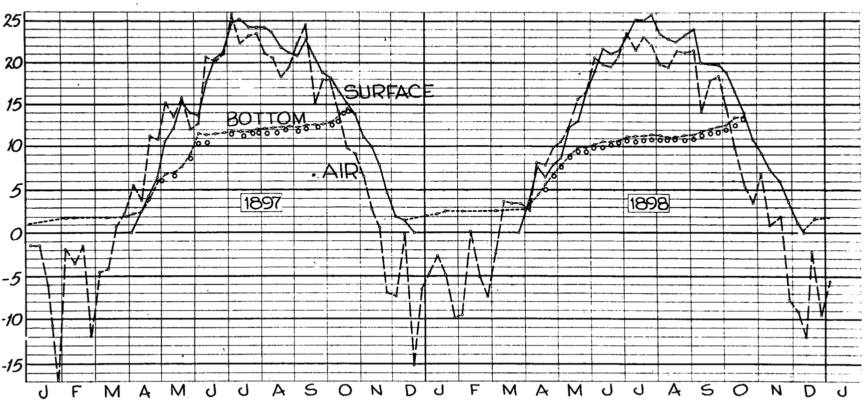

FIGURE 30. Temperatures in Lake Mendota during 1897 and 1898.

8.5° and the bottom an average of 7.6°, a difference of less than a degree, which was uniformly distributed through the entire depth. After the first week in May, however, the surface gained rapidly in temperature as compared with the bottom (see also Fig. 28). The average for the second week in May was, at the surface, 12.2°, a rise of 3.7°, while the bottom temperature had risen less than 1°. The temperature difference was, however, distributed with approximate uniformity. During the following week the bottom water rose in temperature about 0.6° and after that date increased very slowly, since between the third week in June and the last week in August the temperature rose only from 9.1° to 10.7°. During the period the vertical distribution of temperature became progressively unequal. An inspection of the temperature curves (Fig. 28) shows that nothing which can fairly be called a thermocline appeared until the second week in June, and that at this time the phenomenon was only slightly marked. After the third week in June, however, a thermocline was established beginning at a depth of about 6 m. and from this date until the last of September it was constantly present, its upper surface sinking in that time about 8 m., from about 6 m. to 14 m. In 1897 (Fig. 27) the thermocline was not established at so early a date, since it could hardly be regarded as fairly present before the first week in July, and the same date may be given for its establishment in 1896 (Fig. 26).

These dates may be given as those marking the establishment of what may be called a permanent thermocline, as determined by the weekly averages. If, however, the presence of a stratum of water in which the temperature falls rapidly be taken as indicating a thermocline, such phenomena are present temporarily at a much earlier date and quite frequently. For example, on May 16, 1898 at noon the temperatures were as follows:

Surface	12.6°
9 m.	11.0
10 m.	9.9
11 m.	9.8
22 m.	8.7

At this time there was obviously a slight thermocline between 9 and 10 m. On May 23, the temperatures were as follows:

Surface	15.0°
11 m.	13.8
12 m.	13.0
13 m.	13.0
13.5 m.	10.8
14 m.	10.7
22 m.	9.3

At this date there was obviously a marked thermocline between 13 and 14 m. At numerous dates subsequent to this similar phenomena were observed, of which some further examples are given here:

May 5, 1899, 6:20 a.m.	
Surface	10.2°
8 m.	10.0
9 m.	9.1
10 m.	8.8
20 m.	8.2

(fall of 0.9° between 8 and 9 m.)

May 10, 1899, 6:00 a.m.	
Surface	11.8°
4 m.	11.3
5 m.	10.8
6 m.	9.6
7 m.	9.3
10 m.	8.8
20 m.	8.2

(fall of 1.2° between 5 and 6 m.)

May 10, 1897	
Surface	10.8°
6 m.	10.6
7 m.	10.2
8 m.	8.7
9 m.	8.2
10 m.	7.7
15 m.	6.9
20 m.	6.7

(fall of 1.5° between 7 and 8 m.)

Their explanation is quite simple. The thermocline marks the depth to which the wind has distributed the warmth of the surface water, and on the dates of these observations the warmth had been distributed to the depth named. Later, under the action of the wind, the distribution went on still further, and the warmth was more or less completely distributed to the bottom of the lake.

During the early part of any season, a temporary thermocline of this sort may be formed at any depth between the surface and the bottom of such a lake as Mendota. If in the early spring there occurs, as not infrequently happens, a period of several days of warm and relatively calm weather, such a temporary thermocline may be formed, which may actually affect the weekly averages. For example, the diagram in Fig. 26 shows that between the first and second weeks of May, 1896 a thermocline began to be formed at about the depth of 16 m., and the diagram in Fig. 2 shows that in the following year a similar temporary thermocline was formed, whose effects were visible in the averages of the second and third weeks of May, and whose top lay at about 8 m. below the surface. In both of these cases, the thermocline was practically obliterated and the distribution of temperature became once more nearly uniform through the lake.

The Thermocline of Lake Mendota (1899)

It is a difficult matter to determine exactly the thickness of the stratum which should be included in the thermocline. There is ordinarily no trouble in limiting it at the top, but at the bottom it passes off gradually so that no sharp line marks its lower limit. If it is arbitrarily limited to the region where the rate of descent of temperature equals or exceeds 1° per m., its thickness, as determined from the weekly averages, is from 3 to 4 meters, as may be seen from Figs. 25, 26, 27 and 28. In a lake like Mendota, however, these averages mean comparatively little, since the thermocline is continually varying in thickness as well as in position. The isotherms are alternately pressed together and drawn apart by the action of the wind. This is shown very well in Fig. 31, which gives the daily observations from July 27 to August 6, 1898. The thermocline during this period remained at about the same level, but an inspection of the diagram will show that its thickness varied very greatly. On the afternoon of July 30, the thermocline was nearly 6 m. thick, while on the morning of August 5 it was hardly more than 2 m. in thickness. The same facts are shown in Fig. 32, which shows in a much more striking way the influence of the wind, both in changing the level of the thermocline and in alternately approximating and separating the isotherms. Changes of

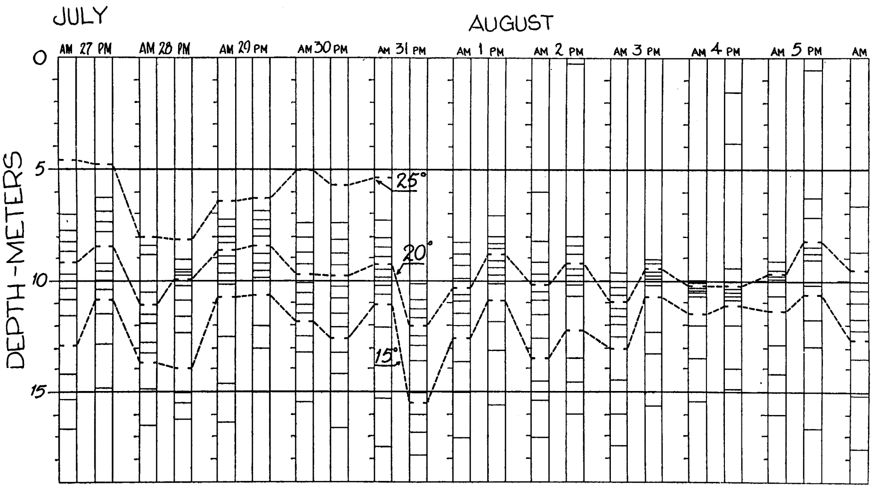

FIGURE 31. Daily temperature observations in Lake Mendota, July 27 to August 6, 1898. Diagram shows the depth at which particular temperatures lay at each observation.

this sort are occurring to greater or less degree all of the time and the level of the isotherms and their distance from each other are subject to hourly change within narrow limits and to much greater changes under the influence of exceptionally strong winds.

It is obvious that the position of the upper surface of the thermocline is subject to great variations. Those variations are wholly irregular and dependent upon the meteorological conditions. Fig. 32 shows one of the most conspicuous of these variations, the upper surface of the thermocline sinking more than 7 m. in 24 hours under the influence of the wind, and rising more than 4 m. in the course of the following 12 hours. These oscillations are, of course, wholly irregular, and, while the average range could readily be stated, the figures have little or no significance on account of the irregularity of the fluctuations.[2] During a period of quiet weather

[2] At this point in his career, Birge apparently did not consider the possibility that changes in the position of the thermocline might be periodic, and might be related to

the thermocline may remain at about the same level for several weeks, while if the wind is violent its level may oscillate greatly within the course of a few hours. No oscillation has been noted greater than that shown in Fig. 32.

The isotherms included within the thermocline vary somewhat from year to year and vary also with the time of year. During the early part of the summer, when the epilimnion[3] is gaining heat,

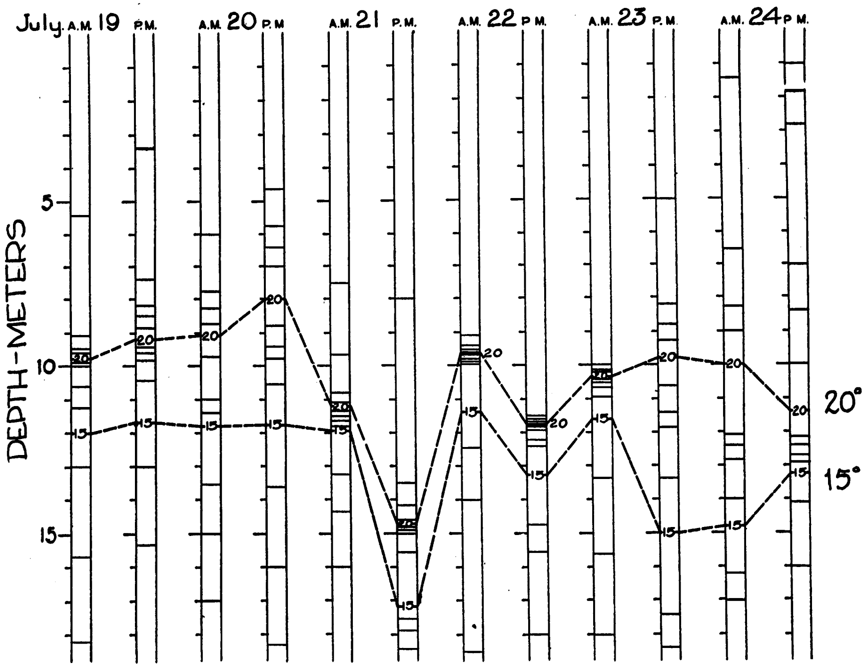

FIGURE 32. Daily temperature observations in Lake Mendota, July 19 to July 24, 1898. Diagram shows the depth at which particular temperatures lay at each observation.

additional isotherms are being drawn into the thermocline. During the later part of the season, as the epilimnion cools, these isotherms are, of course, removed, and at the same time the lower isotherms

former, rather than immediate, wind-stresses. Later, he doggedly refused to recognize the existence of seiches (cf. Birge, 1910). It is most unfortunate that no sections of the 1916 manuscripts have been found describing oscillations of the thermocline. None of the data adduced by him in this section (prepared in 1899) actually suggest periodic oscillations in Lake Mendota, and, so far as we have been able to discover, neither did any of the data then available to him. This was not true, however, in 1916 (see Mortimer, 1956), and it would be interesting to see if the opinions expressed in the (1910) critique of Wedderburn's description of a seiche in Loch Ness had undergone any modification. Ed.

[3] Throughout the 1899 manuscript, Birge used the terms "superthermocline" and "subthermocline" for epilimnion and hypolimnion. We have made the substitution so that the terminology would be uniform in the two versions. Ed.

may be brought into the bottom of the thermocline. Fig. 25 and those following show in general the range of temperature in the thermocline during summer, which is about as follows:

1895—15° to 21° or 22° = 6° to 7°
1896—17° or 18° to 22° or 23° = 4° to 6°
1897—15° to 21° or 22° = 6° to 7°
1898—14° to 22° or 23° = 8° to 9°

The number of degrees included in the thermocline ranges, therefore, from 5° or 6° to 9° or even 10°, varying in different years and also varying with the time of year. If the temperature of the hypolimnion is low, as in 1898, more degrees will be included in the thermocline than if it is high, as was the case in 1896. The course of the spring warming has, therefore, a considerable influence on the range of the thermocline, since the epilimnion reaches about the same temperature in every year.

The figures given above show the average number of degrees included in the thermocline, but this number is subject to irregular variations somewhat parallel to those in the level of the thermocline. These variations can readily be seen from Fig. 32. In the readings of July 24 the thermocline can hardly be said to begin until the isotherm 19° has been reached, while on July 22 and 23 the thermocline plainly begins at the isotherm 23°. Similar changes go on at the bottom of the thermocline, as can be seen from the same diagram. The isotherm 15° is usually included within the thermocline, but on the morning of July 22 it belongs plainly to the transition stratum. It follows, therefore, that the thermocline is continually varying in the number of degrees which belong to it, as well as in thickness. The greatest number of degrees noted has been 9.

The maximum decline of temperature per meter within the thermocline is also subject to great variations. The average maximum, as shown from the weekly averages, only exceeds 3° by a very little. The maximum, as taken from single observations, is, of course, much greater than this. The greatest decline noted during the regular observations was on July 26, 1897, where there was a fall of 8.7° between 11 m. and 12 m. and of 7.8° from 11 m. to 11.5 m. On July 11, 1900, the temperature at 11 m. was 21°, falling to 13.5° at 11.5 m. and to 12° at 12 m. The wind was strong from the north at this time. On numerous occasions in all years a decline of from 6° to 7.5° has been noted in a single meter. Undoubtedly somewhat higher figures than these could have been obtained by careful watching of opportunity. These readings were taken at the regular place of observation. Undoubtedly greater decline could be found nearer shore or in bays, etc.

It should be noted that the great oscillations of temperature at certain levels, as shown by the diagrams that give the diurnal observations, do not involve a correspondingly great range in the level of the thermocline. If Fig. 31 is examined it will be seen that the level of the thermocline does not vary as much as would be expected from the great oscillations of temperature shown at the 10-meter level during the same time. For example, the temperature at 10 m. fell 6.3° during August 3, but the level of the upper surface of the thermocline shifted during that time less than half a meter. During the following nights the temperature at the 10-meter level rose 5.6°; the level of the thermocline shifted less than a meter. In the night of August 4 the temperature fell 4.8° at the 10-meter level but the top of the thermocline shifted only a few centimeters.

From what has been said, it will be plain that no diurnal oscillations of the thermocline can be observed which are dependent on the action of the sun or on cooling at night. The amount of the sun's energy which would reach the upper level of the thermocline —say 8 to 10 m.—is so small in Lake Mendota that no appreciable diurnal effect would be expected from the sun's action at that depth, nor would the cooling at night in the early part of the season extend so far as the thermocline. As herein explained, the effects of the diurnal warming and cooling are probably not manifest below an average depth of 5 m. and therefore take place altogether in the epilimnion during summer. Even if it were theoretically possible that there should be a rise of the thermocline during the day, caused by the action of the sun, the oscillations which are caused by the wind are so great, rapid and irregular that the effect of the sun, if present at all, would be entirely obscured.

The upper level of the thermocline moves downward during the summer. At first, during the latter part of June and early part of July, somewhat rapidly, and during the remainder of July and until the latter part of August, much more slowly. This average downward movement is generally very constant in the weekly averages in spite of irregular and often great fluctuations. Occasionally the upper level of the thermocline rises as compared with the preceding week, as shown in the third week of July, 1896. Such a rise very rarely affects the entire thermocline, although one or two isotherms are frequently raised or lowered in this way by the action of the wind. The average downward movement of the thermocline depends on two factors: 1. the energy of the wind and 2. the temperature relations of the epilimnion. If the temperature of the epilimnion is rising, it is much more difficult for the wind to affect the level of the thermocline than is the case if the temperature of the epilimnion is falling. In the former case, there is a more or less rapid warming in the epilimnion which may extend to its bottom. The number of degrees included in the thermocline is therefore increasing, and there is also an increase of the resistance which the thermal stratification of the water offers to mechanical mixture. When the temperature of the epilimnion is falling, no such thermal resistance is presented to the mixture of the water of the epilimnion with the upper layers of the thermocline, and the mixture goes on much more rapidly.

The rate of descent of the thermocline varies, therefore, very greatly in different years. In 1896, for instance, its downward movement from the latter part of June to early September was rapid and fairly constant (Fig. 26). Its descent was somewhat checked by the two periods—one in July and one in August—when the temperature of the surface water reached 25° or more. In 1898, on the other hand, the movement of the thermocline from the first week in July to the last week in August was very small. The isotherm 20° lay at 9.2 m. at the first-named date, and at 10.2 m. on the last; the entire downward movement in seven weeks was only one meter. In 1897 and 1895 the rate of movement was intermediate between that of 1896 and 1898. In all cases the thermocline showed a rapid downward movement in September, together with a decrease in the number of degrees included within it, both phenomena due to the cooling of the water. This autumnal downward movement varies greatly in rapidity in different years, according to the rate at which the lake cools and the amount of stormy weather in September. In 1897 the downward movement, as shown by the isotherm 15°, was fairly uniform until into October. In 1896, on the other hand, the rapid downward movement began early in September, the isotherm 16° sinking more than 6 meters during that month. In this matter also, the temperature of the bottom water makes a considerable difference. If this temperature is low, the thermal resistance offered to the sinking of the thermocline is correspondingly great, and the surface water must fall to a lower temperature before it can be mixed with that at the bottom. This was the case in 1897 and 1898, while in 1895 and 1896, when the bottom temperature was relatively high, the sinking of the thermocline during September was correspondingly rapid.

The rapidity with which the thermocline descends during the early autumn will depend on three factors: (1) the amount of wind, and especially on the storms of the summer and early autumn, (2) the rate at which the upper water cools, (3) the temperature of the water below the thermocline and at the bottom of the lake. Nothing need be said by way of explanation of the first two factors. The influence of the third factor is also obvious. The temperature at the bottom of the lake may vary in different years as much as 5°, say from 10° to 15°. If the bottom temperature is low, the thermal resistance offered to the sinking of the thermocline under the action of the wind will be correspondingly great, and the temperature of the upper water must fall correspondingly before the wind is able to mix it with the water of the bottom. Under these circumstances, the descent of the thermocline will be retarded and the homothermous condition of the lake will come on relatively late in the season. If, however, the temperature at the bottom during the summer is 15°, or anywhere near that, the temperature of the upper water will need sink only a little below 20° before the action of a strong wind will be sufficient to bring about a homothermous condition. The temperature of 20° is likely to be reached in the early part of September and under these circumstances the descent of the thermocline in the middle and latter part of that month will be correspondingly rapid. It is perhaps possible that direct insolation plays a part in the descent of the thermocline in lakes whose waters are more transparent than those of Lake Mendota, or in which the thermocline lies nearer to the surface, though I do not see very clear proof of this. It is not at all probable, however, that the sun aids in the descent of the thermocline in Lake Mendota. At all events, any action which it may have is entirely obscured by that of the wind.

The descent of the thermocline, which in the diagrams depends on the weekly averages, seems fairly uniform, but is really very far from regular. The rise of temperature at the 10 m. level for instance, is dependent on occasional large oscillations of temperature rather than upon anything like a steady gain; after each set of oscillations the temperature never returns to the level which it had before the disturbance took place. This rise in average temperature at the 10-meter level means, of course, a corresponding lowering of the thermocline and it is easy to see that the thermocline may remain almost stationary for several weeks and then may suddenly descend for a considerable distance. Such a rapid descent is seen in the interval between the first week in August and the first week in September, 1898, where all the isotherms below 20° sank nearly a meter in one week, or through a distance greater than that through which they had moved in the course of the preceding seven weeks. Something of the same sort is seen in the latter part of August, 1896, as compared with the preceding weeks.

According to the observations made on Lake Mendota, the upper surface of the thermocline is quite irregular. Ule (1898, p. 49) describes this surface as being convex. According to him, the sun warms the shallow water at the margin of the lake to the bottom, so that the marginal water at a given depth reaches a higher temperature than the deeper water in the middle of the lake. The cold water, therefore, rises as a sort of mound or hill in the middle of the lake, and from this elevation horizontal streams of water flow toward the margins of the lake in order to equalize the vertical distribution of temperature. Corresponding warm currents flow inward from the margin.

On 24 different days during 1897 observations were made on Lake Mendota at a series of buoys anchored at various distances from the shore and extending from the depth of 10 m. to 19 m. When the observations were begun, the upper surface of the thermocline was at a depth of about 10 m. No such phenomenon as that described by Ule was detected on any occasion. The upper surface of the thermocline moved up and down on the shore, as it does in

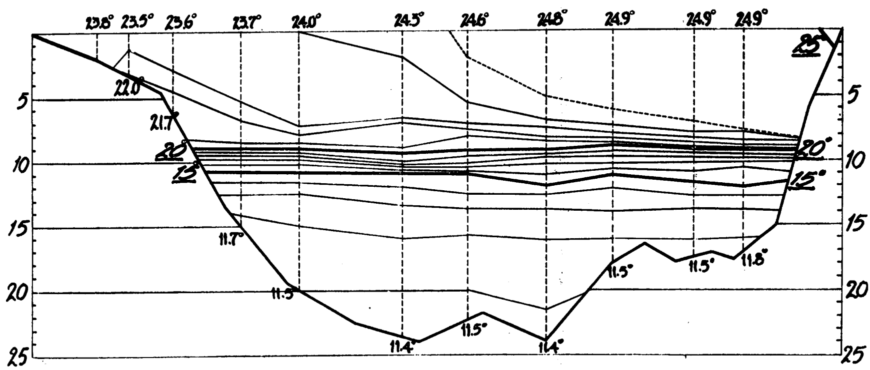

FIGURE 33. Distribution of temperatures across the basin of Lake Mendota, July 9, 1898. The location of this profile is shown in Fig. 1.

the open water, and with a somewhat greater range of motion. No convexity, however, such as described by Ule, could be detected. The thermocline in Lake Mendota lies at such a depth that the effect of the sun is lost before it is reached at the depth of 10 m., so that no such convexity of the upper surface would be expected in this lake. Ule's phenomenon, however, can be found in the shallower water of the lake, as shown by the profile diagram for July 9, 1898 (Fig. 33; location of transect shown on Fig. 1). At about three o'clock in the afternoon of that day the water in the shallow bay on the north side of the lake had a temperature of 23.8° at the surface and 23.7° at the bottom, about 2 meters below. A little farther out, at a depth of 3.5 m., the surface temperature was 23.5°, the bottom temperature 22.0°. The distribution of the temperature was that described by Ule, but at a depth so small that no effect on the thermocline could result from it. Inspection of the diagram will show that the phenomenon did not extend into deeper water. I fail to find any observation of Ule's which proves that the surface of the thermocline has the shape assigned to it, and while the action of the sun would tend to produce the result assigned, I am sure that in all the lakes which I have investigated the thermocline lies so far below the surface that these effects would be imperceptible at that depth. Hergesell, Langenbeck, and Rudolph (1892, p. 173) find no such convexity of the upper surface of the thermocline. Thoulet (1894, pp. 578–579) shows this surface substantially as I find it in Lake Mendota, but his section of Longemer presents a surface of the thermocline much more irregular than my observations would indicate. Since, however, his observations—58 in number—were taken at different times on three days and irregularly distributed through the space covered by the observations, it is hardly possible that they accurately represent the surface at any one time. Undoubtedly, the surface of the thermocline fluctuated from hour to hour, as is the case in Lake Mendota.

Ule (1898, p. 61) finds that the temperature of the bottom of the thermocline is that of the spring-water which enters the lake. This is obviously not the case in Lake Mendota, nor would such a relation be expected since the amount of water thus supplied is infinitesimal in comparison to the cubic contents of the lake. The summer temperature of Merrill's Springs, by far the largest which flow into the lake, is 9.2° and deep wells in this region range from about 8.5° to 10°. Since the water at the bottom of the lake ordinarily reaches a temperature decidedly higher than the upper limit of the temperature of the spring water, it is obvious that the bottom of the thermocline has no relation to this temperature. This relation may obtain in certain lakes but in all cases it must depend on the relation of the amount of ground-water entering the lake to the volume of the lake and also on the depth at which the ground water enters.

THE HYPOLIMNION (1899)

Lake Mendota has no stratum in which the temperature remains constant. Not only is the bottom temperature far above that of water at maximum density, but in the deepest part of the lake the temperature may fluctuate at brief intervals over a range of several tenths of a degree. The rise of temperature in the bottom water may be brought about in two ways:

1. by mixture with the surface.
2. by mixture with a higher and a warmer stratum of water at some distance below the surface.

The first kind of warming happens occasionally during the spring and has been discussed in connection with the spring warming of the lake. The second method is going on all of the time. As the warm water near the surface of the lake is driven from side to side by the changing action of the wind, the surface of the cooler strata below must necessarily change to adapt themselves to the varying thickness of the epilimnion. This change of level necessarily causes currents in the thermocline and lower strata, whose general direction is horizontal, but which result in slow mingling of the strata in which the currents occur. These currents are so feeble that they cannot overcome to any considerable extent the thermal stratification, but they are sufficiently strong to mingle adjacent strata.

Such currents are necessarily most vigorous in the thermocline and immediately below it, and they gradually die out in force as the depth increases. They extend, however, to a much greater depth than can be found in Lake Mendota. In the Weissensee, for example, Grissinger (1892) found a constant temperature at 40 m. and below, but a temperature which varied at the depth of 35 m. The Weissensee has an area of 6.6 sq. km., although its great length (11.9 km.) enables the wind to exert a powerful influence on it. In Lake Geneva, Wisconsin, whose area is 22.3 sq. km., I have found fluctuations of temperature at the bottom (43 m.); in Rainbow Lake similar variations are found at a depth of 25 m., although the total area of the lake is less than 1 sq. km. In Lake Mendota at a depth of 23 m. variations of temperature may occur from day to day amounting to as much as 0.4°.

Wherever such variations occur, the temperature of the water is sure to rise. It might be thought possible that these currents would simply mix the water of the hypolimnion, causing a rise of temperature in the lower part of this stratum, but a fall in the higher regions. Such, however, is not the case. The same wind which sets up these currents causes also a mingling of the lower strata of the epilimnion with the upper part of the thermocline. There is, therefore, a constant gain of temperature from the surface of the lake downward, and the whole body of water is gradually warmed by a more or less complete mingling of each stratum with the warmer stratum above it. This process goes on with considerable rapidity when the thermocline is first established and when the isotherms included in it are relatively few. In the middle of summer, when the thermocline has been carried downward to a greater depth and has become concentrated, the thermal resistance which it offers to these currents becomes greater and the effect of the currents in the hypolimnion becomes much smaller, so that there may be a midsummer period of several weeks during which the average bottom temperatures do not change perceptibly. For example, from the first of July to the last of August, 1898, the bottom temperatures rose only 0.3°. If, however, the bottom temperatures at the opening of the summer are lower, a very much greater rise is possible. In 1899, for example, the temperature of the bottom water at the middle of July was only 9.6°, and by the 25th of August it had gained 0.6°.

Temperatures at the Bottom (1916)

The bottom temperature, as measured on the central plain of the lake, at 22–24 m., has a mean in late August of 12.5°. The lowest temperature has been 9.9° in 1909, the highest 14.8° in 1896. The highest temperature is nearly a degree above the next highest, 13.8° in 1915. The next to the lowest is 10.7° in 1898. All the others reach 12.0°, or more.

The bottom temperature of Lake Mendota is peculiarly connected with the accidents of the weather rather than with its larger features. The heat is very rapidly distributed through the 24 m. of water until the temperature of 4° has been passed, and no notable slowing of distribution is found until that of 6° has been reached. But in general, after this the rise of the bottom comes very irregularly. Its nature may be well seen in Fig. 19, which shows in detail the story for 1914. The bottom temperature on April 15 was 4.4° and it rose pretty steadily until April 30, when it stood at 6.1°. On May 1 came a high north wind and on May 2 the bottom stood at 6.8° and at 7.2° on May 3. It remained between 7.6° and 7.5° until May 11, when another cold, high wind brought it up to 9.1°, after which its rise was slow and steady, to 10.0° on about May 30 and to 10.6° by July 1.

Fig. 34 shows the results of daily observations made in 1899. In that year the main rise occurred on April 28, May 2 and May 12–14. In these three periods came the rise from 4° to 10° or over, while the period from May 22 to July 1 added little more than a degree to the bottom temperature. In this diagram, the period

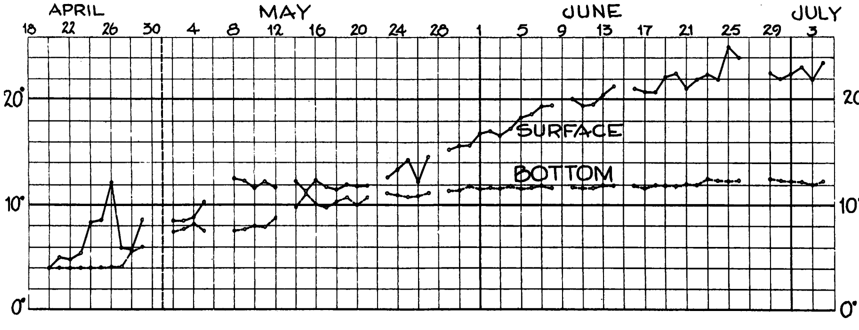

FIGURE 34. Temperatures of surface and bottom water, spring and summer, 1899.

April 20–28 is especially instructive. In the earlier days of this period the surface rose rapidly from 4° to 12.3° while the bottom was not affected. Then followed a cold and windy period in which the surface fell to 5.7° and the bottom rose to 5.2°, which was followed in turn by another departure and another approach on a higher level early in May. On May 15 the surface was 11.3° and the bottom 11.0°; but the latter temperature was not permanently established.

In general, then, the bottom water makes its great gains of heat during two or three cold, windy periods, chiefly found in April and May, but occasionally in June. During the first week of June, 1917, the bottom temperature rose nearly 2.0°, but such great gains at so late a date are exceptional.

No exact rule can be stated as to the conditions of surface or air temperature, wind and sun which will bring about one of the sudden rises here noted. The factors are numerous and they both aid and hinder the distribution of heat. The length of time that the more vigorous part of the wind lasts is an important factor. Free mixture of upper and bottom water may almost occur and yet the bottom water settle back with little change. A few hours, or even a few minutes more of wind might have made an important difference in the result. A degree more or less in the surface temperature, under given conditions of wind and air temperature, may in similar way determine whether a cool wave will notably affect the distribution of heat or will have little influence.

There is, therefore, in Lake Mendota a period of circulation of the water in the spring, but the circulation is much less complete than in autumn except during the period when the general temperature of the water is below 4.0°. After this temperature has been passed, the surface constantly tends to depart from the bottom and the conditions shown by the diagram of 1899 are sure to recur. During warm periods the temperature of the surface rises while that of the bottom remains stationary. During the following cool period the temperature of the surface declines, much of the heat of the upper water is distributed through the lake, and the temperature of the bottom rises nearly to that of the surface. But practically, a completely homothermous condition is never reached in the sense in which that word may be fairly applied to the lake in autumn. If seeming exceptions occur in the observations, they are shown to be temporary, due to the action of the wind, and disappear as soon as the normal stratification of the water returns.

The general temperature of the bottom water, then, is due to the accidents of weather, which bring about large increases of temperature in a day or two. On the number and extent of these events depend the main points in the story of the bottom temperatures. But besides these great and sudden rises there is a slow and fairly steady rise of the bottom water from week to week. The mean chart (Fig. 21) shows that the bottom reaches 11.0° about June 1 but does not get to 12.0° until about July 11, and more than 2.5 months are needed to add another degree. Indeed, the mean temperature of 13.0° is only reached just before the rapid rise, when the lake "turns over" in the autumn. This slow and fairly steady rise amounts to a little less than an average daily gain of 0.03° in June, slowing to about 0.016° in July, and declining to almost nothing in August. It is due to the slow mixture of bottom water with that above it, under the influence of currents and oscillations due to wind. It is greatest in June because the thermocline is then not fairly established and the wind can more readily affect the mass of the water. It slows in July and August, when the effect of the thermocline is at a maximum and the velocity of the wind is least. But oscillations of the water are always going on, some caused directly by the action of wind on the surface water, others, both regular and irregular, indirectly due to wind. All of them create differential movements of the different strata of water and thus slowly mix the warm upper strata with those immediately below. This action is most vigorous at the thermocline, but it continues more slowly and less effectively even to the bottom of the lake, and thus brings about a slow addition to the warmth of the bottom water.

The effect of these oscillations is also seen in constantly recorded changes in bottom temperature. The same temperature is rarely found in successive observations at the same station. Variations of 0.1°–0.2° are common even in midsummer and later and those of 0.3°–0.5° occasionally appear. These are due to the currents in the deeper water, which constantly bring new water to the point of observation. The currents are caused directly or indirectly by wind, and may be fairly regular in their movement (temperature seiches) [sic] or, more often in Lake Mendota, they are irregular. In any case they bring along the bottom at any point of regular observation water from different levels of the lake, and therefore of different temperature. Not only so, but in a lake whose bottom like that of Mendota shows a large nearly flat area in the middle, the isotherms of the deeper water do not run horizontally. The area of the coldest water, in the bottom meter or two, is always smaller than would be expected from the map. Mixture with warmer water is constantly going on around the edges of this coldest portion, under the influence of oscillation of the water, and its area is thus being reduced. As the wind and currents shift, this coldest water is moved about on the bottom plain, causing irregular oscillations in the bottom temperatures.

These variations in bottom temperatures appear in the numerous sets of observations made on single afternoons of 1911 to 1914 at different stations of the lake. On September 16, 1911, the bottom at station H gave 12.8° at 22 m. while station I gave 12.2° at 23.5 m. and 12.6° at 20 m. On June 13, 1911, station I gave 12.8°, which was 0.2° *above* the reading at H at 22 m. On September 21, 1912, exactly the same readings were made. On July 21, 1912, the bottom at 23.5 m. was 0.1° above that at 22 m. Numerous similar observations could be recorded.

Thus the observed temperatures of the bottom in the deepest water are subject to constant change, and this change may be greater than is likely to come from a tilting of the isotherms under the influence of the wind. This also occurs and can readily be assigned to its proper cause. But even during calm periods the temperature of the bottom may oscillate, though by a greater range than the difference between the temperature at 20 m. and that of the bottom at the point of observation, 3.5–4 m. deeper. Such variations occur when the observations in the thermocline show that there are no general oscillation of the lower water, which are even near this vertical magnitude, so that it is impossible that water from the 18- or 20-meter level should be carried down to 23 m. or deeper.

The difference in temperature between surface and bottom varies much in different years. The mean maximum difference derived from the weekly means of 16 years is 13.4°; the greatest found is 16.4° in 1916, July 4; the least is 9.3° in 1915, June 3. If the lowest-observed bottom temperature at the maximum temperature of the water (9.9°) is subtracted from the highest mean weekly surface temperature (29.4°) the difference is 19.6°, which may be taken as the greatest possible difference so far as these observations go. The greatest difference found in a single observation is 20.3° (33.4° — 13.1°) on July 29, 1916. The lowest possible difference from the weekly means, computed by subtracting the greatest bottom temperature found in summer from the smallest maximum surface temperature is 8.0° (22.8° — 14.8°). In general, therefore, we may say that the probable maximum "spread" of temperature in the lake is 11.0° to 16.0°, with no marked tendency to concentrate near the mean, about 12.5°, that the possible minimum "spread" is about 8.0°, though none has been observed below 9.3°, and that the possible maximum is about 20.0°, though none has been observed above 16.4°. The "spread" of single series has risen above 20.0° on one occasion and to 19.7° on another, June 30, 1910.

The week of maximum difference is ordinarily in July and coincides with the week of maximum surface temperature. At this time of year the surface varies much more than the bottom and a hot wind causes it to warm rapidly. In three years of the sixteen on record the maximum difference has come in the last week of June; those in July have been distributed as follows: July 1, 2; 2, 5; 3, 1; 4, 5.

Fig. 24, which gives the mean temperature chart of the lake, shows a rapid descent of the 13.0° isoline in September, indicating a rapid warming of the bottom water at that time. The same fact is indicated in the other figures. The bottom temperature, after a long period of very slow increase, rises rapidly at the end to meet the declining surface temperature. This sudden rise usually measures a degree or more. It is due to the overturning of the lake under effect of the fall gales. Since these are periods of rapidly falling temperature for the water in general, the maximum point reached by the bottom is not likely to be recorded. The observations give the result at the close of the overturn, not the highest point reached during the process.

There is not much to say of the bottom temperature during the fall homothermous period. In general, it sinks with the surface, though on the whole slightly faster. An exact agreement of surface and bottom is not commonly found during this period; surface temperatures below those of the bottom are also rare except on cold and calm days; very commonly the surface is 0.1°–0.2° above the bottom, even in the early morning. This condition is ordinarily due to the wind. The surface water is blown across the lake, cooling as it goes; it sinks on the lee side of the lake and returns along the bottom. After a hard blow, the lee side of the lake may be occupied by the colder water and the isotherms, dividing this water from the warmer, may run at a steep angle rather than nearly horizontally. After such a blow the lake returns to normal stratification with the colder water at the bottom.

A second and somewhat different method of securing colder bottom water is also possible. The shallower water may cool by radiation on calm clear nights. If such a night is followed by a bright day with light south breeze, the warmer surface water from the middle of the lake will be blown into Catfish Bay and will override the colder water of its shallows without mixing with it. This water will then sink along the bottom until it reaches the deepest part of the lake. This process of "interning" a mass of colder water was traced in detail on one occasion, and no doubt happens not infrequently. It must occur in summer also but its effects can be traced only when the water is cooled below the temperature of the bottom and, therefore, does not mingle with water at intermediate depths.

Thus it happens, from various causes, that the water at the bottom of the deepest part of the lake, during the period of fall circulation ordinarily shows a temperature below that which the upper water at the same place has reached. This result is brought about in spite of the fact that the lake loses its heat by way of the surface.

AUTUMN (1899)[4]

In a deep lake no line can be drawn between the summer and the autumn conditions of temperature. In such a lake the bottom temperatures are so low that the water does not become homothermous until late in November, not very long before the time of freezing. But in a lake so large and so shallow in proportion to its area as is Lake Mendota, the thermocline often reaches the bottom quite early in the autumn, and while the average temperature of the water is still high. There is, therefore, a period of considerable length between the time when the thermocline reaches the bottom and the date of freezing. During this time the lake is usually not exactly homothermous, but the differences between the top and bottom do not exceed a few tenths of a degree, so that we may speak of an autumnal homothermous period even more accurately than of a similar period in the spring.

The date on which the lake becomes homothermous varies greatly in different years and the temperature of the water at this time varies correspondingly. Several factors determine this date. Among these may be mentioned (1) the temperature of the surface water during the summer, (2) the temperature of the bottom water, (3) the rate of cooling of the water during September and October and (4) the amount and the direction of the wind during the early autumn.

The first of these factors is the least important. The temperature of the surface water in the latter part of September is not widely different in different years. The temperature of the surface on the last day of September varied from 16° to 20° in the years 1895–1900. The lowest temperatures, 16°–17°, were found in 1895 and 1896. In these years the temperature on the 26th and 27th of the month was 19°–20°, so that the variation of surface temperature in the latter part of September is really less than appears from temperatures taken on the last day of the month.

The bottom temperatures are more variable. Temperatures taken in the deepest water of the lake about the middle of August—the date that best represents summer conditions—are as follows:

1895—13.8°	1898—10.9
1896—14.6	1899—12.1 (July 18)
1897—11.6	1900—10.2

[4] This section was corrected by hand to include data obtained in 1900. Ed.

No temperatures were taken in the late summer and autumn of 1899.

It will be noticed that the temperatures in 1895 and 1896 were decidedly higher than in any of the following years and that the cooling during the latter part of September was also more rapid in these years (cf. Fig. 29). The surface and bottom temperatures, therefore, approached within 2° or 3° of each other at the latter part of the month. In fact, the approach was nearer, since there is a slow increase of the bottom temperature during the month of September. As a result of this mutual approach, the thermocline moved downward rapidly in the cold storms which in these years marked the last few days of September, and during these storms or in the days immediately following them, the lake became approximately homothermous at a temperature of about 16°. The following tables will show the facts in more detail:

1895	September 27	October 4
Surface	19.3°	16.5°
Bottom	18.6	16.3

1896	September 20	October 1	October 3
Surface	17.2	15.8	15.1
Bottom	14.9	15.0	15.0+

The bottom temperatures, as given above, represent the highest temperatures observed during the years in question. In 1897 there was no such sudden fall of temperature in late September, as was the case in the two preceding years, and while the thermocline moved down to a depth of 14 m. by the end of September, it remained near that depth for some weeks and it was only on October 23 that the lake became substantially homothermous. At this time the temperature at the surface was 14.9° and the bottom 14.6°. This was the highest temperature which was found at the bottom during this year and indicated a rise of 3° from the bottom temperature at midsummer. In 1898 the thermocline reached about the same depth in late September as in the preceding year, and the subsequent equalizing of temperature went on much as in 1897, but the homothermous condition was reached at a lower temperature. On October 19 the surface and bottom temperatures were 13.8° and 13.5° respectively, the latter being the highest temperature observed during the year. It is not probable that any completely homothermous condition was reached until some days later, as warm days followed and it was not until the 27th, after the weather had turned cold, that surface and bottom temperatures of 10.6° and 10.4° were found. In 1900 the fall of temperature was even slower than in any of the preceding years and the bottom temperatures were also lower. As a result, the homothermous condition was not reached until well into November. The highest bottom temperatures were reached on November 2, when surface and bottom showed 14.5° and 13.9° respectively, and a week later a completely homothermous condition was found on November 9 with a temperature of 11.0°.

Thus the beginning of the homothermous period in Lake Mendota has varied nearly five weeks, from a date approximately the first of October to the opening of the second week in November, and the temperature at which the homothermous condition has been reached has varied from nearly 17° to about 14°.

It will be observed that the homothermous condition has not been reached in several of the years until the bottom temperature had fallen considerably below the maximum which it reached. This is due to the fact that these figures probably represent only in part an accurate statement of the facts. The wind has so much influence on Lake Mendota, shifting the warmer water from side to side of the lake, that observations taken at any given point will frequently show a small difference in temperature between the top and bottom, while observations taken at another point, where the influence of the wind is different, might show a homothermous condition. At the same time, since the bottom water of the lake is warming and warming somewhat rapidly during the time when the homothermous condition is approaching, and since this warming depends on the progressive mixture of the bottom water, not with that of the surface but with that of the strata immediately above it, it is obvious that the homothermous condition of the lake and the maximum temperature of the bottom water would only coincide when the latter was brought about during a gale so violent as to overturn the entire mass of water of the lake. This condition was practically reached in 1895 and 1896, but not in any of the succeeding years. The existence of a long period in the later years, during which there was only a slight difference of temperature between top and bottom, depended upon the fact that during these days or weeks there was no wind of sufficient intensity to bring about a complete overturning of the water. The overturning probably happened only after the entire mass of water had cooled below the temperature of the bottom and an inverse stratification was present. It is obvious that the accidents of wind and weather must make the process of equalization of temperature very different in different years.

After the lake has become practically homothermous, the temperature continues to fall at a rate varying with the conditions of the weather. The surface and bottom of the lake are nearly equal in temperature and it is very rare that an inverse stratification is found during the day. The action of the sun ordinarily causes the surface strata to be slightly warmer than those at the bottom. During the night the stratification becomes inverse, although differences between top and bottom rarely exceed 0.2° or 0.3°.

The following table gives the approximate date when the lake reaches the temperature of 4°:

Year	Date when 4° was reached	Lake froze	Temperature
1895	November 25	December 14	1.2°
1896	November 25	December 21	1.4
1897	November 28	December 17	0.5
1898	November 25	December 9	0.15
1900	December 6	December 26	0.6

The preceding table shows that from 14 to 27 days may elapse between the dates when the lake reaches the temperature of approximately 4°, and the date of freezing. During this time the thermal stratification is necessarily inverted, as the surface water becomes lighter as it cools. The difference, however, between the top and bottom continues small, the lower water falling in temperature nearly as rapidly as that near the surface. The maximum differences between the surface and bottom found during this period are as follows:

1895—1.0°
1896—2.2
1897—1.3
1898—1.0
1900—0.7

The deeper water of the lake and the shallow water near the edge sometimes show noteworthy differences in temperature. On numerous occasions, differences ranging from 0.2° to 1.0° have been found during November and December between the temperature of the surface at the regular observing stations and that found in perhaps one meter of water at the pier at the boathouse. If temperatures are taken in the very shallow water at the edge, still more considerable differences may be found, as is seen by the following observations made November 23, 1898:

Depth of Water	Temperature of Surface
18 m.	4.9°
10 m.	4.9
5 m.	4.9
3 m.	3.1
0.2 m.	0.6

It frequently happens that the lake freezes at the edge while the temperature is still considerably above freezing in the open lake. On November 29, 1898, the morning was calm and cold; the surface temperature in water 18 m. deep was 4.45°. In water 5 m. deep the surface was 3.6°, and nearer shore where the water was 1 m. deep a surface temperature of 0.8° was found. At the shore temperatures of 0.1° and 0.2° were observed at the surface and 2.2° at the bottom, and a thin film of ice soon formed, extending out far beyond the position of the 5 m. contour. This endured, however, but a few hours.

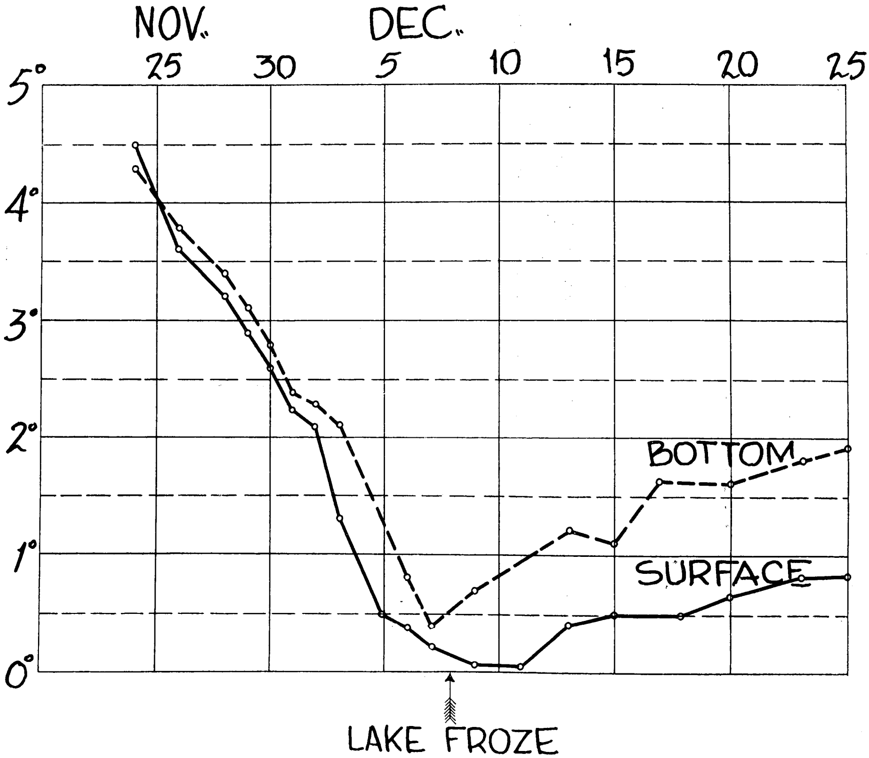

FIGURE 35. Temperatures of surface and bottom water, November and December, 1898.

Since the whole body of water in Lake Mendota cools at so uniform a rate, it is obvious that there can be no *barre thermique* formed, as described by Forel for Lake Léman (1895, p. 377).

The accompanying figure (Fig. 35) shows the relation of surface and bottom temperatures in Lake Mendota during the latter part of November and December, 1898. It will be seen that the inverse thermal stratification began on November 25, but that the difference between surface and bottom was ordinarily only a small fraction of a degree. The rise of temperature after freezing, both at the surface and bottom, is plainly visible and will be discussed in connection with winter temperatures.

It is not impossible, theoretically, that the water of a lake should reach, in whole or in great part, a temperature of 0°, but it is very improbable that such a low temperature should actually occur before the lake froze. When the temperature has fallen below 1°, ice forms on the lake if the air is cool, even during considerable wind. If there is wind enough to cause the waves to break, the bubbles of foam thus formed freeze and make nuclei around which collect spicules of ice, and there are thus formed cakes of ice varying from a few inches to several feet in diameter, which are driven before the wind and accumulate on the leeward side of the lake. Under favorable conditions a mile or more of water in Lake Mendota may be covered by these cakes and occasionally the lake closes almost entirely during such a wind, the closure being completed as the wind is falling. Still more easily does freezing occur if no wind blows. In either case the rate of conduction in water is so slow that the layer at a temperature of zero would be very thin. If, however, a water temperature of 0° is not reached before the lake freezes, it will not be reached later, since it is not conceivable that the loss of heat by conduction and radiation should be greater than, or even equal to, the gain which is received from the sun. It should be noted, however, that the temperature of the water near the ice is very close to 0°. This can easily be demonstrated by cutting a hole through the ice and leaving it for a day or more, until the water, disturbed by filling the hole, has regained its normal temperature. It will be found under these circumstances that the water in the hole has a temperature little or not at all exceeding 0°, but that a few centimeters below the ice the temperature is usually 0.6° to 1.0°. The thermophone is by no means an instrument well-adapted for finding the temperature of very thin strata of water. Yet it has been usual to find temperatures of 0.1 to 0.2° when the coil was just below the ice. Temperatures between 0.0 and 0.1° were regularly found in the water standing in the hole cut in the ice.

The rapid rise of temperature in the water immediately below the ice has often been remarked by different observers and Lake Mendota always shows it. On a February 15, for example, the temperature of the water in a hole cut in the ice was less than 0.1°. When the bottom of the thermophone coil was on a level with the lower surface of the ice it was 0.1°. Lowering the coil about 5 cm. gave a temperature of 0.2°. Upon lowering it 15 cm. more the temperature rose to 1.2°. Thus in a stratum not exceeding 15 cm. in thickness, the temperature rose more than 1°. Beyond this point it rose more slowly until at 1.5 m. below the surface the temperature was 2°. This rapid rise is not difficult to explain even though the temperature of the water at the time of the freezing of the lake may have been close to zero. When the ice has reached any considerable thickness, very little, if any, of the energy of the ultra red rays succeeds in penetrating it and reaching the water below. The warming of the water is due entirely to the energy of the visible portion of the spectrum. This, however, will penetrate the water to a considerable depth and will be converted into heat by a considerable thickness of the upper strata of the water. The heat will not be communicated in essentially greater degree to the stratum of water immediately below the ice than to an equally thick stratum situated several centimeters lower down. Thus, part of the heat communicated to the water by the sun is so placed that it will not be lost by contact with the ice, and as the conductivity of water is exceedingly small, it is not surprising that the temperature of the water rises rapidly from 0° at the ice to a temperature of 1° or more within the distance of a few centimeters. It is obvious also that if, under these circumstances, a hole is cut through the ice and the water allowed to rush in and fill it, the surface temperature *thus obtained* will be at least a considerable fraction of a degree above 0°, and it is not at all surprising that when temperatures are measured in this way it is impossible to obtain readings in the neighborhood of 0°. It appears to me that this effect of the sun shining through the ice and warming the water is a sufficient explanation of all the facts observed in connection with surface temperatures in winter, and that while further observation will undoubtedly disclose many interesting details, there are no serious problems to be solved regarding the temperature of the water just below the ice.

Two other matters remain to be discussed: First, in what way is the cooling of the lake affected after the temperature has fallen to 4°? Lake Mendota remains open for a very considerable length of time after this temperature has been reached, as is shown by the following table:

1894—November 14, 7.4°; December 3, 2.0°. Lake froze December 28.
1895—November 23, 4.9°; 27, 3.2°. Lake froze December 20; 21 days.
1896—November 22, 4.4°. Lake froze December 21; 25 days.
1897—November 27, 4.1°. Lake froze December 16; 19 days.
1898—November 24, 4.8°; 26, 3.6°. Lake froze December 8; 13 days.

During this period, varying from 13 days to more than a month, the lake is cooling and ordinarily cools by 2 or 3° or even more. All the observations made on Lake Mendota show that during this time the temperature is nearly uniform from top to bottom. A calm day will show differences of a few tenths of a degree between surface and bottom, but even no very strong wind is needed to obliterate these differences. This fact of approximate uniformity of temperature shows that the wind is able to create currents in the lake extending to its bottom. It is unnecessary, therefore, to assume, with Forel (1880),[5] that the conductivity of water has been underestimated by physicists. Richter's argument that the cooling cannot depend upon the action of the wind (1897, p. 49), since the thermocline is not disturbed by the strongest wind at a depth of 8 to 10 m., does not apply to water in which there is no thermal stratification to resist the action of the wind. All the temperature phenomena of Lake Mendota show that the action of the wind during fall and spring extends to the bottom of the lake. All other lakes of Wisconsin, including Green Lake, the deepest in the state with a maximum depth of over 70 m., show similar phenomena.

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[5] Birge here is making much out of some more innocent remarks of Forel, whose attention had been drawn in 1879 to a paper by Buchanan (1879) in which it was demonstrated from temperature soundings in Loch Lomond and Linlithgow Loch that the temperature of the bottom water of lakes in winter could fall well below 4°. In 1880 Forel himself obtained three winter temperature profiles, two in Lac de Morat and one in the Zürichsee, which he compared with Buchanan's data in several essays published in 1880. In one of these (1880a) he makes the following comment: "Ces expériences [of Buchanan] ont un grand intérêt en montrant que la conductibilité de l'eau pour la chaleur est bien plus important que l'on ne pouvait le supposer, ou, pour être plus prudent, que la propagation du froid descend bien plus bas que l'on ne le croyait; . . .", and then concludes the essay with: "Il ne nous reste d'action efficace que la propagation de la chaleur de bas en haut, par conductibilité ou conduction, les couches inférieures livrant leur chaleur aux couches supérieures, refroidies elles-mêmes par rayonnement et par contact avec l'air. Les recherches classiques de Despretz ont demontré cette conductibilité dans des vases d'expérience; l'observation de la propagation de la chaleur dans les lacs la prouvera d'une manière bien plus grandiose.

"J'ajouterai que c'est à cette conductibilité, et uniquement à elle, qu'il faut attribuer la phénomène d'égalisation de la température que j'ai décrit . . .; dans les quarante jours qui ont séparé mes deux sondages du lac de Morat, la différence de température entre les couches supérieures et les couches inférieures a diminué; la chaleur s'est donc propagée verticalement, de bas en haut, et cela dans un vase fermé de toutes parts, où il n'y a pu avoir ni courants thermiques ni courants mécaniques, mais seulement conduction.

"En résumé, je ne vois pour expliquer les faits constates de la distribution thermique dans les lacs de Morat et de Zurich, que trois actions possibles:

a) convection thermique, circulation de Buchanan;

b) convection mécanique, circulation causée par les vents;

c) conduction de la chaleur.

"Ces trois actions se sont probablement combinées ensemble; j'attribue la plus grande part à la troisième, puis à la seconde, la première de ces actions ayant l'effet le plus faible."

Birge's view apparently is that Forel, clinging to this argument, would be forced eventually to assume that the thermal conductivity of water had been underestimated. On the other hand, Forel himself was by no means quite certain of the mechanism he proposed. In another essay (1880b), discussing precisely the same data (his own soundings in Lac de Morat and Zürichsee and Buchanan's information from the Scottish lochs), he concludes: "Cette pénétration du froid dans les couches supérieures a lieu trés graduellement et progressivement. La courbe que l'on peut tirer de mes chiffres du lac de Zurich ne présente ni sauts ni saccades; elle est tout à fait analogue aux courbes du réchauffement superficiel d'un lac en été. Cela suffit, me semble-t-il, pour écarter la supposition que la refroidissement, que pénètre aussi profondement, ait lieu ou bien par voie de convection thermique ou bien par mélange mécanique sous l'action des vagues et des courants, . . .

"Faut-il attribuer cette pénétration du froid à des phénomènes de conductibilité ou à des phénomènes de radiation, soit de l'eau elle-même, soit du sol à travers l'eau? Les expériences ne me donnent pas d'éléments pour repondre à cette question." Ed.

A second matter is the rise of temperature in the water toward the bottom of the lake and in the mud. During the winter, the temperature, as shown when the coil of the thermophone is resting in the mud, is higher than that of the water immediately above; the difference in temperature is at a maximum in the early part of the winter, almost or quite vanishing just before the lake opens in the spring. The maximum differences observed have been slightly more than one degree, but ordinarily a rise of 0.4° to 0.8° is found in passing to the mud from the water close to the bottom. The amount of rise in the stratum is shown by Fig. 36.

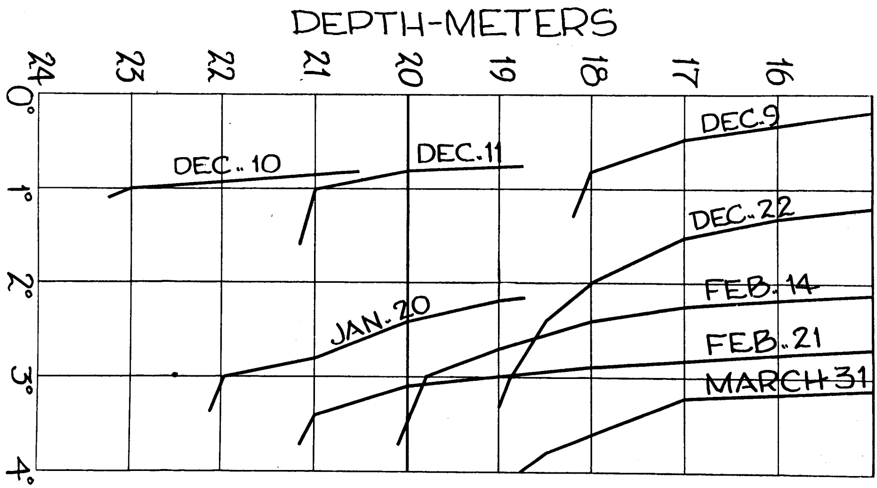

FIGURE 36. Temperatures in the mud and in the lower water on several dates during winter. Profiles were obtained at stations at varying depths.

The cause of this rise of temperatures is mainly the heat of the earth. This warmth must be communicated to the water in two principal ways: first by conduction, second by the passage into the lake of ground water. Which of these two methods is the more efficient in producing the rise of temperature it is impossible to state. It is a fact that on any steep slopes and any small elevations of the bottom, the difference of temperature is absent or is less than in the hollows and in the deeper water of the lake.This, however, would be true in whatever way the rise of temperature was produced. The gain of heat to the lake from this source is extremely small and quite insignificant in comparison to the gain which is made from the sun.

It is also possible that part of this warming of the bottom water is due in part to the action of the sun at the edge of the lake. The water lying, say, a half-meter below the ice in shoal water and receiving warmth from the sun, might flow down along the bottom in consequence of its greater density, and thus cause an accumulation of warmer water in the deeper parts of the lake. There is nc direct proof that such a flow takes place, although it must occur so long as the bottom water is colder than 4° C. It is obviously impossible to distinguish between water thus warmed and flowing along the bottom and the warmer ground water entering the bottom of the lake. To a flow of warmed water, induced in some way, must be due part of the rise in temperature of the lower water, which is always present in winter.

A third point of some little interest may be noted. In 1898 a somewhat rapid rise of temperature was found in the bottom water during the days immediately succeeding the closing of the lake. The water at 16 m. rose in temperature from 0.25° on December 9 to 0.9° on December 15, and at 18 m., from 0.8° to 1.2° in the same time, rising more rapidly than the water near the surface and hence not by heat received from the sun. It was found also that in going to the northwestern part of the lake one found the temperature of the bottom to rise, the maximum difference in going across the lake being about 0.5° at the depth of 17 m.

This rise of temperature in the bottom water immediately following freezing and this difference between the southern and northern sides of the lake, are doubtless due to the wind. Immediately preceding the freezing there was a moderate northwest wind with low temperature. This wind both cooled the water and carried the cold water to the southeastern part of the lake. Thus there arose a difference in temperature; the water of the windward side of the lake was warmer than that on the leeward, or south side. After the lake had frozen, the warmer water on the northern shore flowed along the bottom toward the south under the influence of gravity, displacing the colder and lighter water.

One other phenomenon attending the freezing of lakes has attracted a good deal of attention and has not yet met with any satisfactory explanation. This is the presence of unfrozen areas in the surface of the lake which often remain open for a considerable length of time after the freezing of the lake as a whole. Almost every season such areas are found in Lake Mendota. The places where they appear differ in different seasons and the unfrozen areas vary greatly in extent. In 1898, a space of this kind remained open December 8–16. When observed on the 17th, the ice over this area was about 3 cm. in thickness, while that adjacent to it was 20 cm. thick. The new ice covered a space several hundred meters in length and with a maximum width of perhaps 100 m. The opening had evidently been formed by the moving of the first ice under the influence of the wind, thus leaving a space which had remained unfrozen for a week. The popular explanation of such a phenomenon is that springs below the surface keep the water warm. This, however, is not the case. Were this true, the unfrozen areas would appear year after year in the same situation, which is very far from the fact. Moreover, considerable springs rarely occur in the depths of a lake. The question was carefully investigated with the thermophone in 1898, and no difference in temperature, either at the surface or at the bottom of the water could be found between this open area and the water elsewhere in the lake.

Forel (1898) discusses in detail these open spaces in the ice of Lake Joux, and considers the various explanations which have been proposed for them. He rejects in turn, and with good reason, the connections of these open spaces with springs, with brooks, or with the action of the wind, and also with the possible presence of oil on the surface of the water. The only explanation which he can suggest as a possibility is the disturbance of the water by the large flocks of wild ducks. This explanation he repeats in a later work (1901, p. 129). Since no wild fowl are found in Lake Mendota during the winter season, the maintenance of these open spaces by duck-power is an impossibility here.

I suppose that the true explanation lies in the facts which have already been adduced regarding the warming of the lake by the sun as soon as the surface is covered with ice. The energy of the sun transmitted through the thin ice covering by far the greater part of the lake, warms the subjacent water and by lateral currents the water in the open space is kept so warm that it does not freeze for a considerable length of time. Wind undoubtedly aids in keeping the hole open, partly by mixing the surface water with that immediately below, and partly also, by setting up lateral currents which carry the surface water away from the opening and replace it by warmer water drawn from below the ice. In 1898 the water below the ice rose on the average something more than 0.5° between the 9th and 16th of December, the time during which the unfrozen area was present.

WINTER TEMPERATURES (1916)[6]

The winter period is that during which the lake is covered with ice. The length of this period varies greatly as will be seen from the various tables given herewith. The data were compiled by the station of the U. S. Weather Bureau.

The dates of closing and opening are as follows:

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[6] This section was corrected by hand to include some data obtained later than 1916. Ed.

Closing:
- Earliest .... November 23
- Latest .... January 14
- Mean .... December 17

Opening:
- Earliest .... March 9
- Latest .... May 4
- Mean .... April 7

Ice Period:
- Longest possible .... 162 days
- Longest recorded .... 161 days
- Shortest possible .... 52 days
- Shortest recorded .... 61 days
- Mean period .... 112 days

By the "longest possible" ice period is meant the time between the earliest recorded closing of the lake and the latest recorded opening.[7]

Thus a sixty years' record shows that 112 days is the mean length of the ice period. It must be understood that the length of this period is not capable of very precise determination. The lake may freeze around the edge and remain open for some days in the center. On the relative size of this open water will depend the decision as to the date of closing. The lake often freezes over and opens again before it finally closes, sometimes remaining frozen for a week or more before the temporary covering of ice disappears. There is no current in the lake under the ice and its opening in the spring is due to wind.[8] Large floes of ice often remain for some days after the ice moves. Whether under these conditions the lake shall be called open is again a question of judgment. Ordinarily, however, there is no difficulty in deciding on the date and no difference of judgment would be likely to cause a difference so great as one day in the mean length of the ice period.

The ice period therefore varies from two months to more than five months, averaging about 3.7 months.

The time between the earliest recorded closing and the latest recorded opening is 162 days, only one day longer than the longest period on record, that of 1880–1881. The late opening in that year was due to the enormous snowfall of the late winter, the largest on record. The period between the latest closing and the earliest opening is 52 days, 9 days shorter than the shortest period on record, that of 1877–1878. The ice periods have been distributed as follows, with regard to length:

[7] These remarks apply to the period up to about 1916. Information on all subsequent years is available from the United States Weather Bureau, and has been referred to in more recent publications on Lake Mendota. Ed.

[8] This is not strictly true. Although there have been no publications which include observations of currents in Lake Mendota during the winter, some unpublished data are on file in the Department of Meteorology of the University of Wisconsin, and may also be found in the collection of data referred to in the introduction. Ed.

Length, days	Number of Periods
61	1
75	1
78	1
81– 90	5
91–100	10
101–110	11
111–120	8
121–130	14
131–140	4
141	1
142	1
149	1
161	1

It appears that about 75 per cent of the periods lie between 90 and 120 days, and that within these limits they are almost evenly distributed. Eight periods are shorter than 90 days and eight are longer than 120.

Water Temperatures During the Winter (1916)

Regular observations have been made of water temperature during 13 winters. There is necessarily a time at the closing of the lake when observations cannot be made and another similar period at its opening. The length of this period varies in different years. The accompanying table (Table III–4) shows the date of closing in the several years and the dates of observations next preceding and following.

TABLE III–4

OBSERVATIONS AT CLOSING OF THE LAKE

Winter	Observation Preceding	Date of Closing	Observation Following
1897–8	December 12	December 17	December 18
1898–9	December 7	December 8	December 9
1900–1	December 17	December 24	December 30
1905–6	....	January 1	January 8
1906–7	December 19	December 20	January 5
1908–9	....	December 22	December 25
1909–10	December 15	December 18	December 19
1910–11	December 8	December 9	December 12
1911–12	December 25	December 28	December 29
1912–13	December 19	December 24	December 28
1913–14	January 10	January 12	January 13
1914–15	December 12	December 15	December 18
1915–16	December 20	December 28	December 30
1916–17	December 13	December 15	December 18
1917–18	November 24	December 10	December 12
1918–19	December 19	January 3	January 5

In the winter of 1906–1907 observations were started late. In the other years they were made as early as the thickness of the ice and the state of the weather would permit. The average time elapsing between the closing of the lake and the first observation was 2.7 days, if 1907 be omitted. The average time between the last observation in open water and the closing of the lake was about the same, 2.6 days. In general, therefore, the freezing of the lake interrupts observation for about 5 or 6 days, if care is being taken to secure them.

TABLE III–5

OBSERVATIONS AT OPENING OF THE LAKE

Spring	Observation Preceding	Date of Opening	Observation Following
1897	April 6	April 10	April 11
1898	March 4	March 27	Marsh 30
1899	April 12	April 18	April 19
1901	April 4	April 11	April 11
1906	April 2	April 8	April 8
1907	March 19	March 24	March 25
1909	April 1	April 7	April 10
1910	March 18	March 26	March 26
1911	March 18	March 20	March 21
1912	April 8	April 13	April 15
1913	March 27	April 2	April 2
1914	April 1	April 10	April 11
1915	April 4	April 9	April 9
1916	April 1	April 10	April 10

Table III–5 shows the same facts for the opening of the lake. Omitting 1898, in which the spring temperatures were not closely followed, there were from 2 to 9 days preceding the opening in which no temperatures were taken; the average was about 6 days. In general, there is nearly a week during which the ice is unsafe. On the other hand, it has been possible in 6 years to secure temperatures on the date of the opening of the lake and in 5 more years on the day following.

It has been possible, therefore, to secure records of temperature at a date so soon after the formation of the ice that no appreciable change has taken place, and so soon after the disappearance of the ice that no warming of the water has occurred.

MEAN TEMPERATURE AT CLOSING (1916)

The following table (Table III–6) gives the temperature at the closing and opening of the lake.

TABLE III–6

TEMPERATURE OF LAKE MENDOTA AT CLOSING AND OPENING

YEAR	TEMPERATURE AT CLOSING	TEMPERATURE AT OPENING	GAIN	LENGTH OF ICE PERIOD	CALORIES GAINED δ PER CM.²	CALORIES PER DAY
1897–8	0.70°	2.75°	2.05°	100	2480	24.8
1898–9	0.35	4.10	3.75	130	4540	34.9
1900–1	0.62	2.30	1.68	107	2030	19.0
1905–6	0.45	2.30	1.85	97	2240	23.1
1906–7	1.00	2.90	1.90	94	2300	24.5
1908–9	0.90	2.35	1.45	106	1750	16.5
1909–10	0.47	2.40	1.93	98	2340	23.9
1910–11	1.02	2.80	1.78	101	2150	21.3
1911–12	0.08	2.00	1.92	107	2410	22.5
1912–13	0.55	2.50	1.95	99	2360	23.8
1913–14	0.25	2.40	2.15	88	2600	29.6
1914–15	0.48	2.70	2.22	114	2690	23.6
1915–16	0.29	2.70	2.41	103	2920	23.6
1916–17	0.92	2.30	1.38	116	1610	14.4
1917–18	0.39	2.20	1.81	117	2190	18.8
1918–19	0.27	2.62	2.06	103	2500	24.0

In addition to these winters, observations were made in three earlier years with the following result:

Season	Temperature at Closing	Temperature at Opening
1894–5	0.50°	2.50°
1895–6	1.35	3.00
1896–7	0.45	2.40

In these winters observations were not made so frequently and they are not used in the general discussion. They would not essentially alter the general situation shown by the other years. It appears that the water of the lake has a mean temperature of about 0.60° at the time of freezing, ranging from slightly above 1.00° (or perhaps as high as 1.35°) to less than 0.10°.

The lowest temperature was found on December 29, 1911, the lake having frozen the day before. The readings on that day at station I and station II[9] were as follows:

Depth, m.	0	5	10	15	17	20	22	23	mud
Station I	0.00°	0.00°	0.00°	0.00+°	0.10°	...	...	...	0.50°
Station II	0.00	0.00	0.08	0.18	...	0.20	0.24	0.50	0.90

[9] These are the stations marked J and I respectively on the map in Fig. 1. Ed.

These readings were taken both with a Negretti and Zambra deep-sea thermometer and with a thermophone. Both instruments were compared on the same day with a standard thermometer in melting snow and correction is made for their slight errors.

On the same date readings made at two other stations in the main lake showed the same conditions. A series taken in West Bay near station [G or H][10] showed warmer water there, the mean being 0.35°. If all the water in the lake had been mixed its temperature might have been as high as 0.15°. The temperature of the upper 10 m. for probably three-fourths of the area of the lake was barely above zero. It is not likely that a lower temperature at freezing will be found than that of 1911.

The temperatures at opening are all between 2° and 3°, except that of 1899 in which year the temperature was slightly above 4°. In this year the lake did not open until April 18, more than a week later than in any other year in which observations were made. This partly explains the high temperature, but not fully, since the gain of heat was rapid and steady throughout the winter, exceeding in this particular any other year. The mean temperature at the date of opening is close to 2.60° so that the average gain of heat to the water during the ice period may be placed at about 2°.

The amount of this gain has, apparently, no close correlation with the length of the ice period. If the exceptional year 1898–1899 be omitted, the average gain was less in the years when the ice period was longer than the mean, than it was in the years with a shorter ice period. The greatest daily gain next to that of 1898–1899 was in the year with the shortest period. It should be added that in 1898–1899 the temperature of water from 3 m. to 20 m. was below 3.5°. The higher mean temperature was due to a superheated surface stratum below the ice.

The total gain of heat measured in small calories per square centimeter of the surface of the lake has averaged almost exactly 2500 cal. The season of 1898–1899 was, however, very exceptional, and if it is omitted, the mean of the rest is about 2300 cal. The same result would be reached if the three earlier seasons were included. The range is from 1750 cal. to 2780 cal. or to 4540 cal. in 1898–1899. The mean daily gain is 24 cal. or 23 if 1898–1899 is omitted.

Gain of Heat During the Ice Period (1916)

In Table III–7 are shown the mean temperatures of the water for several days during the winter as derived from more significant observations. In general, the gains of temperature are fairly steady through the winter. There remain during the winter slow currents

[10] The original is uncertain. Ed.

TABLE III-7

WINTER TEMPERATURES OF LAKE MENDOTA ON SEVERAL DATES

	January		February		March		April
	1	15	1	15	1	15	1
1897–8	1.08°	1.38°	1.50°	1.65°	1.77°	2.28°	3.10°
1898–9	1.30	1.72	2.06	2.48	2.77	2.95	3.15
1900–1	0.65	0.76	0.98	1.08	1.30	1.60	2.40
1905–6	0.45	0.60	0.92	1.15	1.40	1.72	2.13
1906–7	(1.00)	1.12	1.18	1.75	2.10	2.54	(4.00)
1908–9	1.12	1.52	1.85	2.00	2.13	2.23	2.40
1909–10	0.70	0.90	1.07	0.92	1.30	1.75	(2.58)
1910–11	1.31	1.50	1.86	2.12	2.35	2.70	(3.40)
1911–12	0.10	0.32	0.62	0.75	0.80	0.93	1.27
1912–13	0.50	0.65	0.80	1.20	0.98	1.48	(2.40)
1913–14	(1.65)	0.25	0.73	0.95	1.22	1.62	2.50
1914–15	0.55	0.70	1.07	1.40	1.60	1.62	1.87
1915–16	0.35	0.60	0.95	1.20	1.38	1.80	2.48
Mean	0.84	0.92	1.20	1.43	1.62	1.94	2.60

in the water [sic] which cause variations of temperature at the point of observation. If distinct loss of heat appears, this is due to a thaw which brings cold water into the lake from melting snow. Stationary periods may or may not have the same explanation. In almost all years there is a more rapid rise toward the end of the ice period (say, in March) than at any earlier time. This is due to the increasing effect of the sun. The means as given in this table are not quite fair since the lake was not always frozen on January 1, and therefore not at its minimum, and sometimes was open before April 1 and therefore had been gaining more heat than if it had been still covered with ice. If these years are omitted the mean temperatures and gains are as follows:

Date	Jan. 1	15	Feb. 1	15	Mar. 1	15	Apr. 1
Mean temperature	0.74°	0.92°	1.20°	1.43°	1.62°	1.94°	2.37°
Gain, degrees C.	...	0.18	0.28	0.23	0.19	0.32	0.43
Gain, calories/cm.²/day	...	15	21	19	16	26	33

The slowing of gain during February is no doubt due to the influence of the "February thaw" to which is to be attributed a decline of temperature in each of ten years, and a slowing of gains in others. The increased gains of March are due to the increased influence of the sun.

There is always an inverted stratification of the lake during the ice-period. The water in contact with the ice has a temperature of 0°; there is then a rapid rise to a temperature, usually about 0.5°, shortly after freezing takes place, then a slow rise until within a couple of meters of the bottom. In this bottom stratum the temperature of the water suddenly rises often as much as 0.5° to 0.8°. This programme is more or less modified by the condition of the weather at the time of freezing. If there has been but little wind the temperature gradient is steeper than if the water has been chilled by the wind. The average rise between the water at 1 m. and close to the bottom at the first winter observation of 12 years has been 0.72°, ranging from 0° to 1.50°. The temperature at 1 m. has been 0.42 with substantially no rise to 5 m.; at 15 m. the mean temperature has been 0.65 and close to the bottom 1.14°.

As soon as the lake closes the temperature of the water begins to rise. If freezing has been preceded by wind the colder water has been blown to the south side of the lake and there is a rise during the first few days at the center of the lake, due to this water's assuming the normal stratification. This change involves neither gain nor loss of heat.

The water loses substantially no heat through the surface during the ice period. Any effect of cold is seen in the thickening of the ice and not in the cooling of the subjacent water.[11] On the contrary, the water gains heat from three sources: (1) directly from the bottom of the lake, (2) from incoming water and (3) from the sun. These sources of heat will be discussed later. This effect is two-fold: (1) a slowly moving current of warmed water flows down from the edges and sides of the lake along the bottom and accumulates in the deeper water; (2) the water below the ice is warmed, becomes denser and sinks, thus distributing the heat. Thus there begins, as soon as the lake is frozen, a fairly steady process of warming the water. This is more rapid toward the bottom, less rapid near the surface. It goes on more rapidly if the ice is free from snow. It is deterred or set back by the entry of cold snow-water resulting from thaws. But on the whole it progresses steadily, as is shown by the rise of the mean temperature.

Figs. 37 and 38 show the temperature of the water at 5 m. and at 15 m. during 12 winters. In the figures the mean temperature at the time of freezing is platted at the mean date of freezing and the temperatures on January 1, 15, etc. are shown and connected by lines. The mean results show that the water at 15 m. gains at first more rapidly and later less rapidly than at 5 m. The difference at freezing between 5 m. and 15 m. is about 0.20°; by February 15 this has risen to more than 0.50°; by March 15 it has fallen again to about 0.25°.

[11] It is apparent that this statement is not entirely correct. Turbulent mixing beneath the ice could transport heat from the water-column to the under surface of the ice. Birge was apparently very uncertain about the nature of currents under the ice. Ed.

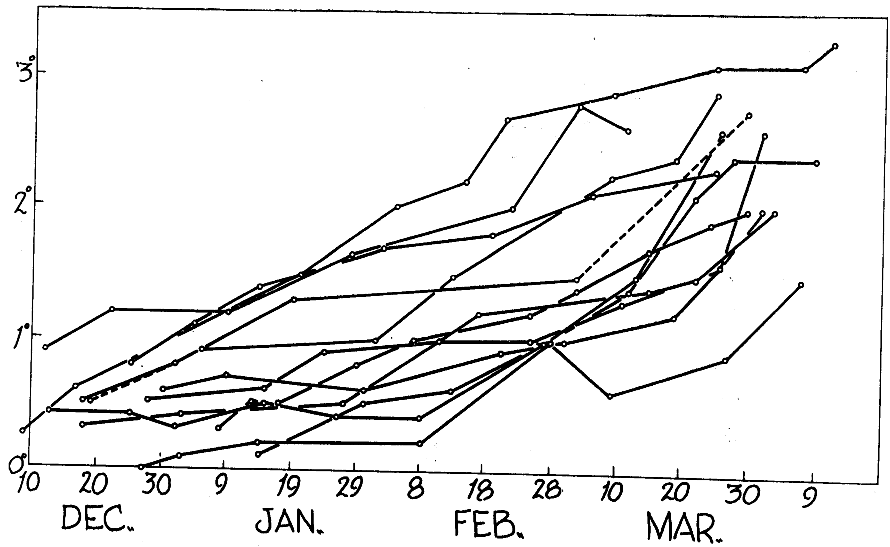

FIGURE 37. Winter temperatures at a depth of 5 meters. Data for 12 winters (see text).

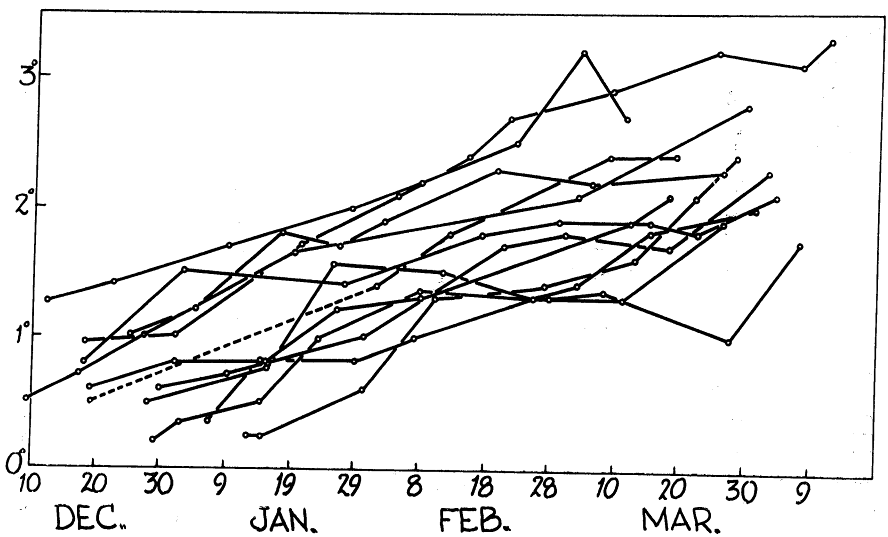

FIGURE 38. Winter temperatures at a depth of 15 meters. Data for 12 winters (see text).

If the general course of the lines in Fig. 39 is followed, the same general conclusion is seen. In Fig. 37 (5 m.) the lines in a few cases rise steadily through the winter from the time of freezing. In more cases, however, they run nearly horizontally until February 1, thereafter rising rapidly. The lines in Fig. 38 (15 m.) show a more rapid rise at first and a decided check in February and early March.

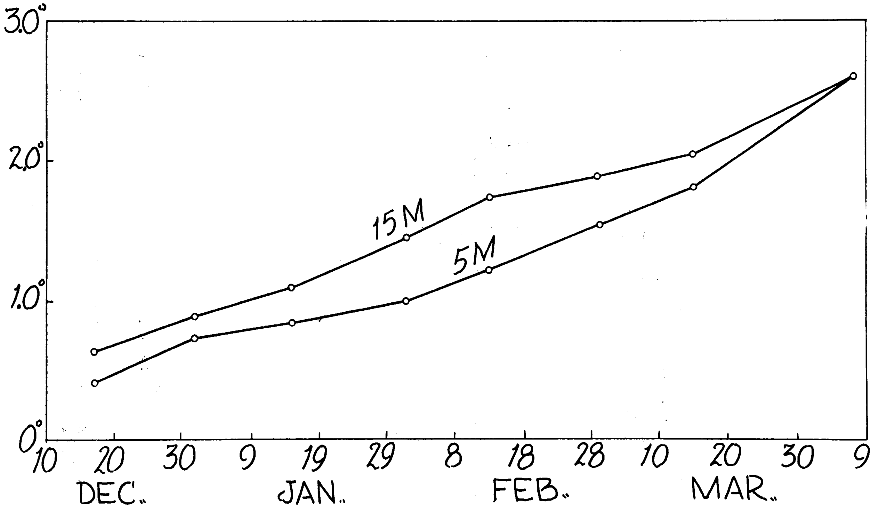

FIGURE 39. Mean temperature during the winter at depths of 5 and 15 meters.

The movement of temperatures at 10 m. is intermediate between that at 5 m. and that at 15 m. The story at 20 m. would be that of 15 m. on a larger scale. But 20 m. is so near the bottom that in many observations the reading fell in the zone of warmed water next the mud; consequently, its mean rate of rise cannot be computed accurately.

IV CHARACTERISTICS OF THE ICE LAYER

ABSORPTION OF THE SUN'S ENERGY BY SNOW AND ICE (1916)

The absorption of energy by ice may be briefly disposed of. Ice absorbs energy in practically the same way as water, if the ice is clear. If it contains air bubbles or inclusions of snow or is becoming crystalline from sun-dissection it may absorb amounts greater than an equivalent thickness of water.

Observations on Lake Mendota on December 28, 1912 showed 37.3 percent of the sun's energy remaining below 7.2 cm. of ice. It must be remembered that the path of the rays in the ice is longer than the thickness of the ice. Readings were taken at noon, but the sun is low in January and February. On January 17, 1913 there was found 18.5 percent below 25 cm. of ice. On February 13 there remained about 3.8 percent below 40 cm. of ice and on February 17, 1913, nearly 7.0 percent was found below 43 cm. of ice. In the later readings, drifting snow and traces of snow in the upper layers of ice made the results variable, but altogether they show that ice behaves toward light in a way essentially similar to water, a result which would naturally be expected.

A good deal of work has been done on the absorption of the sun's energy by snow. In the first construction of the sun machine[12] two receivers were made for it, as it was expected to take readings alternately from a receiver in the water and one in the air. This proved to be unnecessary, but the receiver intended for use in the air has been employed in observations on snow. It is in the form of a large watch and contains 20 thermal couples arranged precisely as in the sun machine. The glass cover over the thermal couples is flat, as in the original form of the sun machine. No allowance for reflection need, however, be made, as the instrument was always placed perpendicular to the sun's rays. The readings were taken with the regular galvanometer of the sun machine.

A box was used to contain the snow, about 25 cm. by 20 cm. Its sides were made of several removable frames, 1, 2 or 3 cm. thick. Thus any depth of snow from 1 cm. to 10 cm. could be used. The receiver was cooled to the temperature of the snow and placed on the bottom of the box, which was filled with snow put in loosely and consolidated by shaking and tapping but not by pressure. The surface was scraped off level with the top of the box and exposed to the sun with the surface normal to the rays. The box was alternately covered and exposed to the sun, and the deflection of the galvanometer noted. Then, removing a frame from the box, one or more centimeters of snow were scraped off and the exposures repeated. Thus the effect of any desired thickness of snow could be studied. The full effect of the sun on the receiver was read at least twice during the series, and usually more often.

As would be expected, absorption of energy by snow is variable. The size of the grains and the compactness of the mass make decided differences. Still further, no standard compactness can be used in observing, since any manipulation of the snow breaks up the flakes or aggregates them. The attempt was made to have the snow as nearly as possible in its natural condition.

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[12] Birge here refers to the electrical pyrlimnometer described in: Birge, E. A. A second report on limnological apparatus. Trans. Wis. Acad. Sci., Arts & Lett. 20:533–552. 1922. Ed.

TABLE IV-1

TRANSMISSION THROUGH SNOW, AS PERCENT OF INCIDENT RADIATION

Date	Thickness of Snow Layer, Cm.							
	1	2	3	4	5	6	7	9
1915								
Feb. 8.......	14.4	5.8	1.4	....	0.5	....	....	....
	14.2	5.3	....	....	....	....	....	....
	....	4.4	....	....	....	....	....	....
	....	4.1	....	....	....	....	....	....
Feb. 9.......	9.0*	3.9*	1.6*	0.7*	....	....	....	....
Mar. 8.......	12.0	5.0	2.3	1.7	0.7	....	....	....
	....	....	4.0	1.3	1.2	....	....	....
	....	....	4.0	2.0	....	....	....	....
Mar. 9.......	....	9.0	4.6	2.4	2.5	1.3	0.6	....
	....	....	4.6	3.3	....	....	....	....
Mar. 10.......	22.6	9.6	5.1	4.1	....	....	....	....
	17.6	6.9	3.8	....	....	....	....	....
	18.1	7.6	....	....	....	....	....	....
	10.6*	....	....	....	....	....	....	....
	10.9*	....	....	....	....	....	....	....
Mar. 11.......	14.1	6.0	3.5	2.1	1.2	0.9	0.6	....
	14.4	5.5	3.6	....	1.5	....	....	....
	12.3	....	3.6	....	....	....	....	....
	12.6	....	....	....	....	....	....	....
Mar. 15.......	13.4	5.6	3.6	2.4	1.2	....	....	....
	15.0	5.0	3.1	....	....	....	....	....
	13.6	....	....	....	....	....	....	....
1916								
Jan. 14.......	19.3	....	3.5	2.0	....	0.9	....	....
	16.4	....	3.9	2.0	....	0.7	....	....
Jan. 16.......	15.7	4.8	2.5	1.3	0.5	0.4	0.2	0.1
	14.5	5.2	2.6	1.3	0.7	0.4	0.2	....
	14.0	5.9	....	....	....	....	....	....
	16.1	3.8*	....	....	....	....	....	....
Jan. 18.......	19.4	7.5	4.7	2.8	1.8	1.1	0.7	0.2
	15.8	7.7	4.2	2.8	1.4	0.9	....	....
	18.1	....	....	....	....	....	....	....
Jan. 31.......	18.6	6.8	5.0	2.9	1.8	1.2	0.5	....
Mean..........	15.7	6.2	3.7	2.3	1.3	0.9	0.5	0.2

*READINGS TAKEN THROUGH VERY COMPACT SNOW

The results of several observations are shown in Table IV–1. It appears that only about 1 percent of the incident energy gets through a layer of snow 5 cm. thick. With this thickness the transmission varied from 2.50 percent to 0.46 percent. The transmission rapidly increased as the covering of snow became thinner, and from 12.0 percent to 22.0 percent are transmitted by 1 cm. of snow, averaging about 14.5 percent. Fig. 40 shows the average curve of transmission as derived from the observations.

Besides these observations, numerous others have been made with less care, but with results entirely concordant. In some cases a glass bottom was put into the snow-box and the regular receiver of the sun machine was used. In this case the thermal couples would be some 4 cm. or 5 cm. below the snow. But the results obtained were within the limits of the series obtained with the other receiver.

Readings have been made through layers of drifted snow so compact that they could be sliced into shape and handled. These showed a smaller transmission, but not greatly less.

It is obvious that the rays of light which reach the glass cover of the receiver through a layer of snow have been so often reflected and refracted that they reach the glass at all angles. There is no doubt loss at this surface by reflection, and a higher percentage of transmission would be shown if the thermal couples could be used without a cover. But the condition which the instrument offers is closely similar to that which the lake presents, where the snow is separated from the water by a layer of ice.

It is obvious from these results that even a thin layer of snow cuts off a very large part of the sun's rays. One centimeter cuts off 85 per cent of the energy and so moderate an amount of snow on the ice as 5 cm. or 6 cm. must practically absorb all of the sun's energy.

It must be remembered in this connection that not a little diffuse light gets through even a considerable thickness of snow. The light of the full moon is by no means inconsiderable but it represents less than $\frac{1}{150{,}000}$ of the energy of the sun.

Insolation Below the Ice (1916)

In the spring the sun's rays penetrate the ice and deliver considerable amounts of heat to the subjacent water. In the last days of the ice period so much heat is delivered as to warm a stratum of the water below the ice far above the ordinary temperatures. This may happen when the ice is from 20 cm. to 35 cm. thick. The first case seen in Lake Mendota is that in which the highest observed temperature was reached. This was on April 12, 1898 when

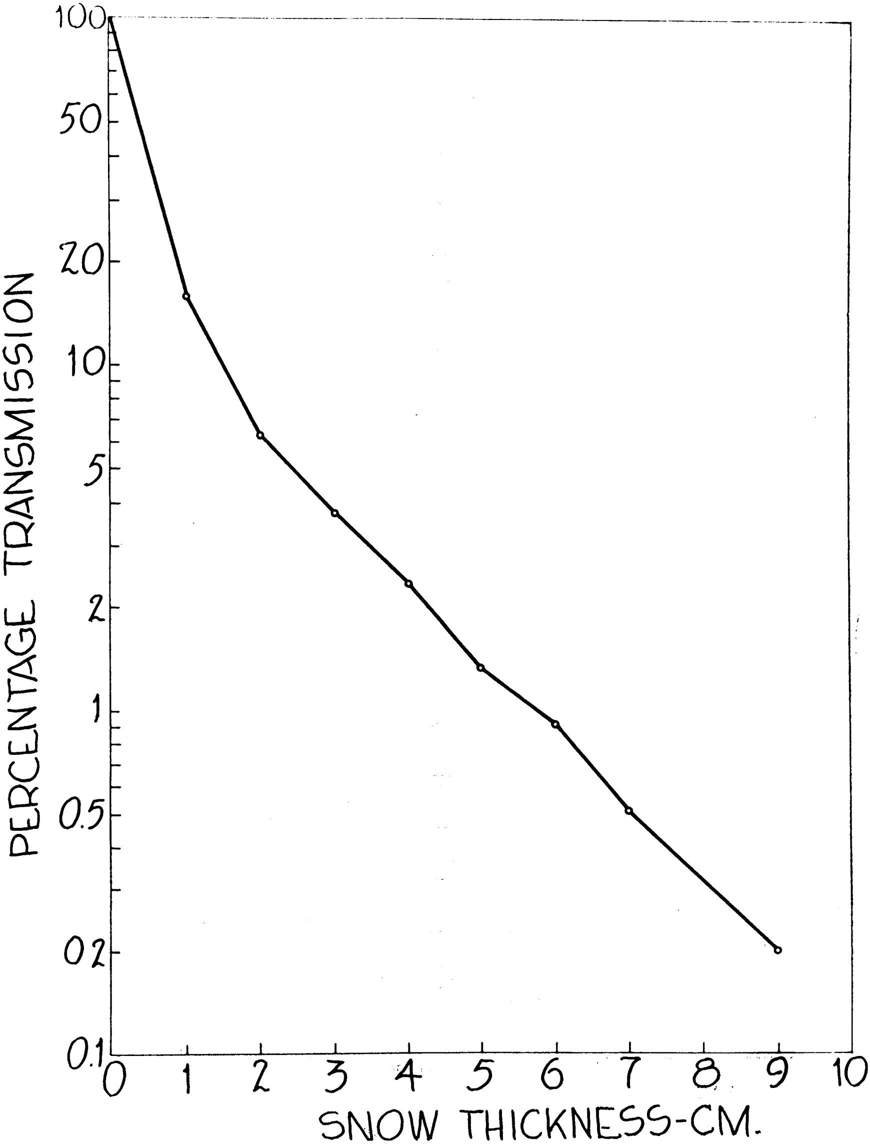

FIGURE 40. Mean transmission of sunlight through snow.

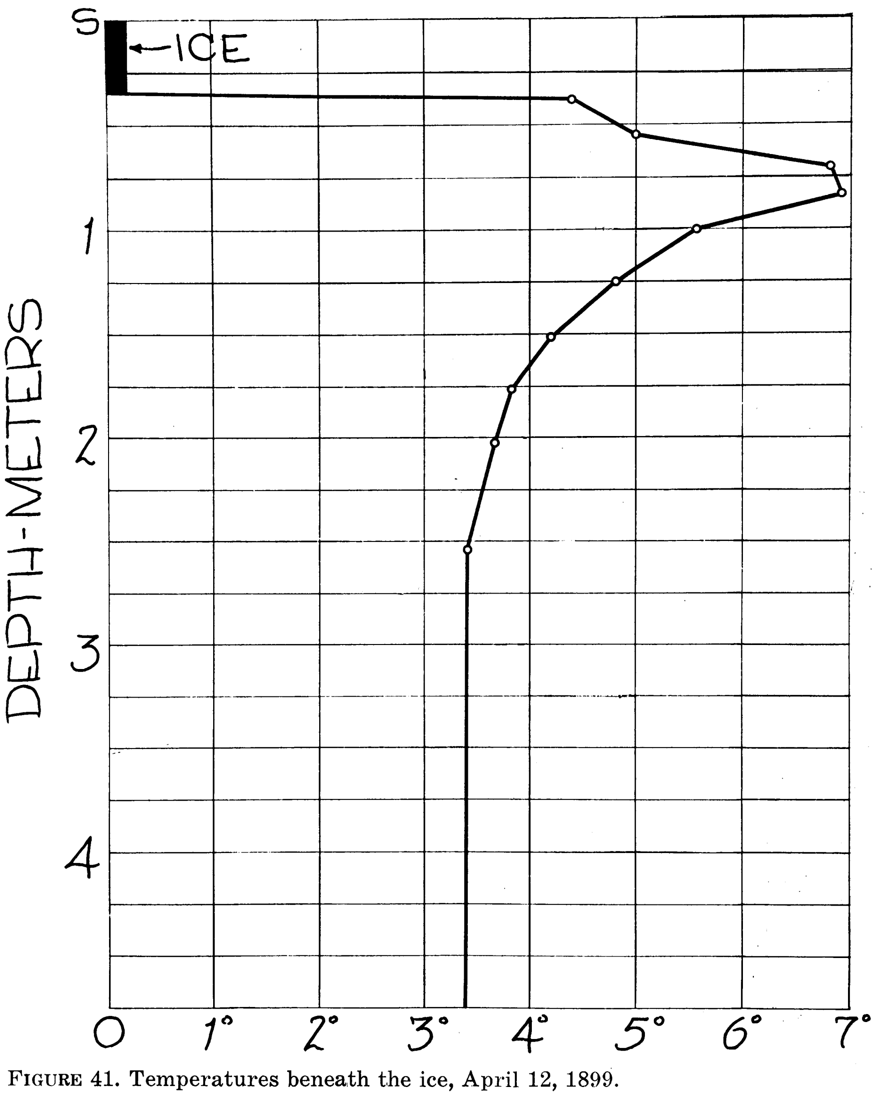

FIGURE 41. Temperatures beneath the ice, April 12, 1899.

the ice was 35 cm. thick and the temperatures were as follows (See also Fig. 41):

Depth, cm.	Temperature	Depth, cm.	Temperature
40	4.4°	125	4.8°
55	5.0	150	4.2
70	6.8	175	3.8
85	6.9	200	3.4
100	5.6	300	3.4

A similar condition existed on April 11 when the maximum temperature was at the same depth, but no reading was made higher than 6.0°. These observations were taken with the thermophone in its older form and represent the temperature of a stratum of water 6 cm. thick, corresponding to the form of the immersed coil. Doubtless the maximum exceeded 7.0° on April 12.

The most careful study of this phenomenon was made in 1901 when the observations continued for several days and even after the ice had begun to move. The results given in Figs. 42 and 43 are selected from a much larger number obtained on the days noted. The temperatures below the ice are not essentially different from those of 1898. The remarkable fact is that the situation should persist after the ice had moved, and even in spite of a gentle breeze which raised wavelets several centimeters high.

The length of time during which this superheated stratum may be found varies much. In 1901 it was not present on March 25 but was noted from March 28 until April 4 and no doubt was present until the lake opened on April 10 and 11. In 1906 it appeared some time between March 8 and March 15. It was last observed on April 3 and should have continued until April 9 when the ice moved out. This period at the shortest would be 24 days (March 15–April 9) and might easily be four weeks in length. Temperatures rose to 6.1° at 50 cm., 6.0° at 75 cm., falling to 3.0° at 100 cm.

It is not always easy to observe this action of the sun. It comes on as the ice is becoming weak and if decay is proceeding rapidly near shore it may be impossible to get out to the firmer ice beyond for some time before the ice breaks up. If the thaw comes with cloud and warm rain the superheated stratum may be little developed or not at all. Probably, however, continuous study, if that were possible, would show that it is always present. It was observed in 1909, 1910, 1915, 1916, besides the three years noted above. In none of these years were temperatures found above 6.4°. In several years when it was expected it was not found.

The height to which temperatures below the ice may rise is extraordinary and their persistence when established is also surprising. Here is a condition of unstable stratification, colder and denser strata superposed on warmer and lighter, and with steep temperature gradients. The latter in 1898, amounted to 1.8° in 15 cm. (5.0°–6.8°), in 1901 to 1.0° in 10 cm. (4.5–5.5°) and 1.9° in about 20 cm. (4.0–5.9°). Under such conditions we should expect to find rapid thermal convection currents promptly established so that temperatures above 4.0° would be quickly equalized. But such is not the case, as is shown by the figures. There is a partial equalization during the night, but a very slow one. More surprising still was the persistence of unstable stratification in open water in 1906.

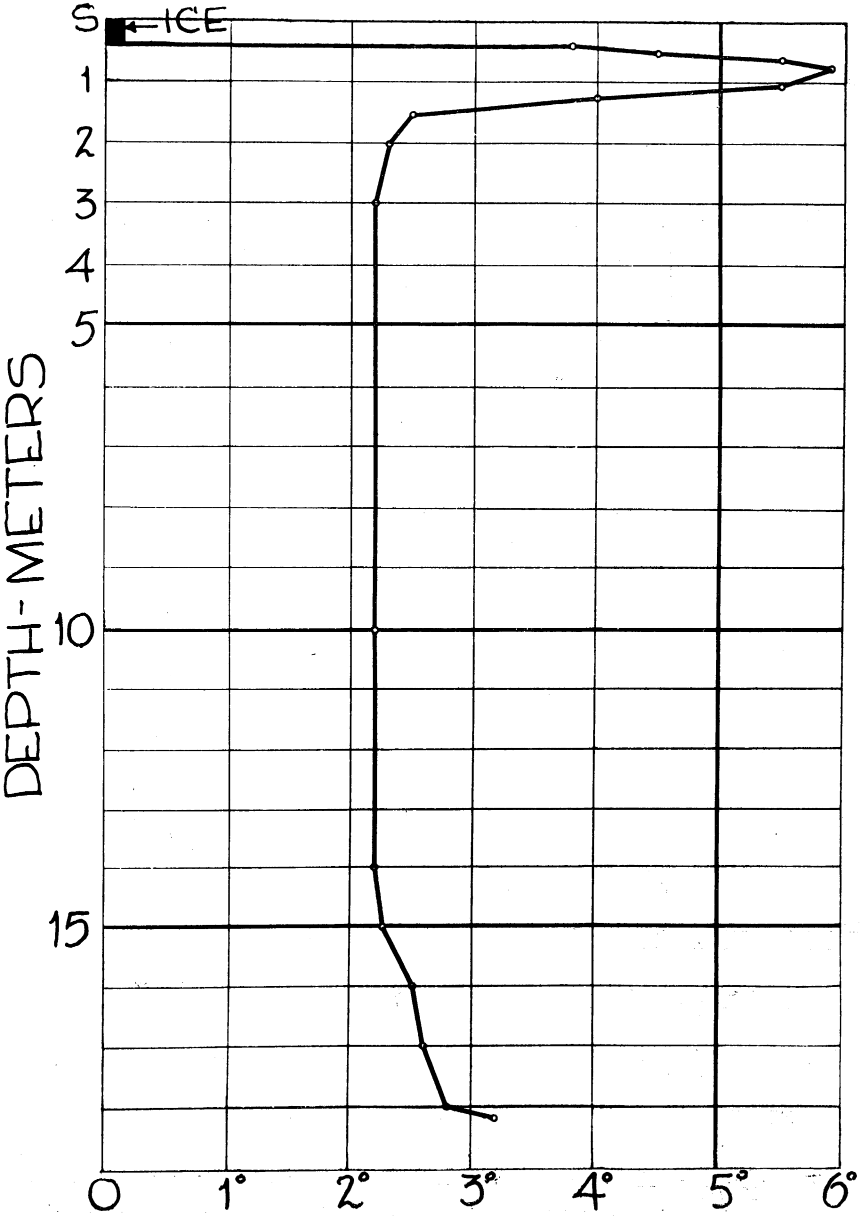

FIGURE 42. Temperatures beneath the ice, April 3, 1901.

It is not easy to assign a definite cause for this slow response to apparent changes in density. Probably there are present more than one factor. A partial cause is the reluctance of diffusion currents to start in quiet water with the small changes of density at temperatures near 4.0°, and a contributing cause may also be the smaller density of the water immediately below the ice. This is water derived from melting snow and ice and so should have less salt in solution than the normal lake water. This relation of density has never been proved but it is made probable by the way in which

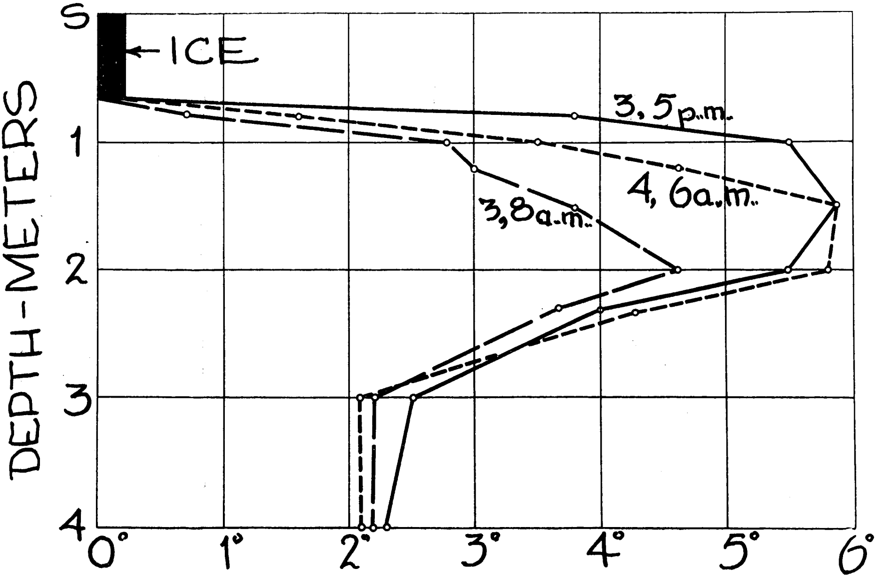

FIGURE 43. Temperatures beneath the ice, April 3 and 4, 1901.

the turbid water after a thaw spreads out in a thin layer beneath the ice, often to distances of a kilometer or more from shore. But if this explanation is accepted, we can hardly believe at the same time that turbidity causes an increase of density such as will set up convection currents. It is also not easy to see how changes of density of this sort should recur at such depths and in such proportions as to neutralize the effects of changes of temperature.

THICKNESS OF THE ICE (1916)

No detailed observations have been made on the growth of the ice or on its thickness. Both are subject to great variations, depending not only on the temperatures of the particular winter but also on the amount of snow and on the amount of wind that accompanies or follows snow storms. A mean rate of growth or a standard minimum thickness are difficult to determine and have very little meaning.

The thickest ice which we have recorded was found in 1899. In that year the ice in February gave a thickness of 68 cm.–74 cm. and on March 7 it measured 70 cm. In 1912 it measured 66 cm. and in 1917, 68 cm.–70 cm. In 1911 no thickness was observed greater than 40 cm. Usually a thickness of 50 cm. or more is reached.

The mean temperature of the air for the month of January, 1912, was —17.2° and for the following 13 days of February it was —15.7°. For more than six weeks beginning January 1st the mean temperature of the air was about —16.8° and at no time during the period did the air rise above zero. In this winter the lake froze on December 28. On January 2 the ice was 10 cm. thick; on January 14 it had increased to 36 cm.; on January 23 it was 52 cm., on February 8, 66.4 cm. and 66 cm. on February 28. It reached a maximum of 69 cm. on March 8. The increase above 66 cm. was due to additions to the upper surface of the ice. Thus the longest period of extreme cold weather on record at Madison added about 56 cm. to the thickness of the ice, increasing it from 10 cm. to 66 cm. During this six-week period, the precipitation was small, being only equal to less than 21 mm. of melted snow, less than one-third of the average amount. The snow, therefore, gave but little protection to the ice.

In 1901 the late Dr. E. R. Buckley, then connected with this [Wisconsin Geological and Natural History] Survey, published a paper on ice ramparts.[13] In this paper Dr. Buckley discussed not only the formation of ice ramparts, but also the expansion and fracturing of the ice. His paper gives several plates showing fractures, etc. in the ice. It was in the winter referred to in this paper that the ice reached the thickness of 74 cm. No greater thickness has been measured during our work on the lake. This partial study is the only one that has been made on the subject.[14] Dr. Buckley intended to continue it, but left the Survey and the state during the same year.

Temperature of the Ice (1916)

In anticipation of Dr. Buckley's further work on the ice, the Survey had made a thermometer for ascertaining ice temperatures. This instrument had a stem some 85 cm. long, covered by a wooden

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[13] Buckley, E. R. Trans. Wis. Acad. Sci., Arts & Lett. 13(1):141–162. 1900 (published 1901). A discussion by C. R. Van Hise is included. Ed.

[14] See: Bunge, W. W. and Reid A. Bryson. Ice on Wisconsin lakes, Part I. Rept. No. 13 to the University of Wisconsin Lake Investigations Committee. 1956. (mimeogr., no pagination). Ed.

case about 2 cm. in diameter. This case at once protected the stem from accident and guarded against sudden changes of temperature. The wooden stem ended in a steel cup which was screwed in the end of the stem. The cup was filled with mercury and in this mer-

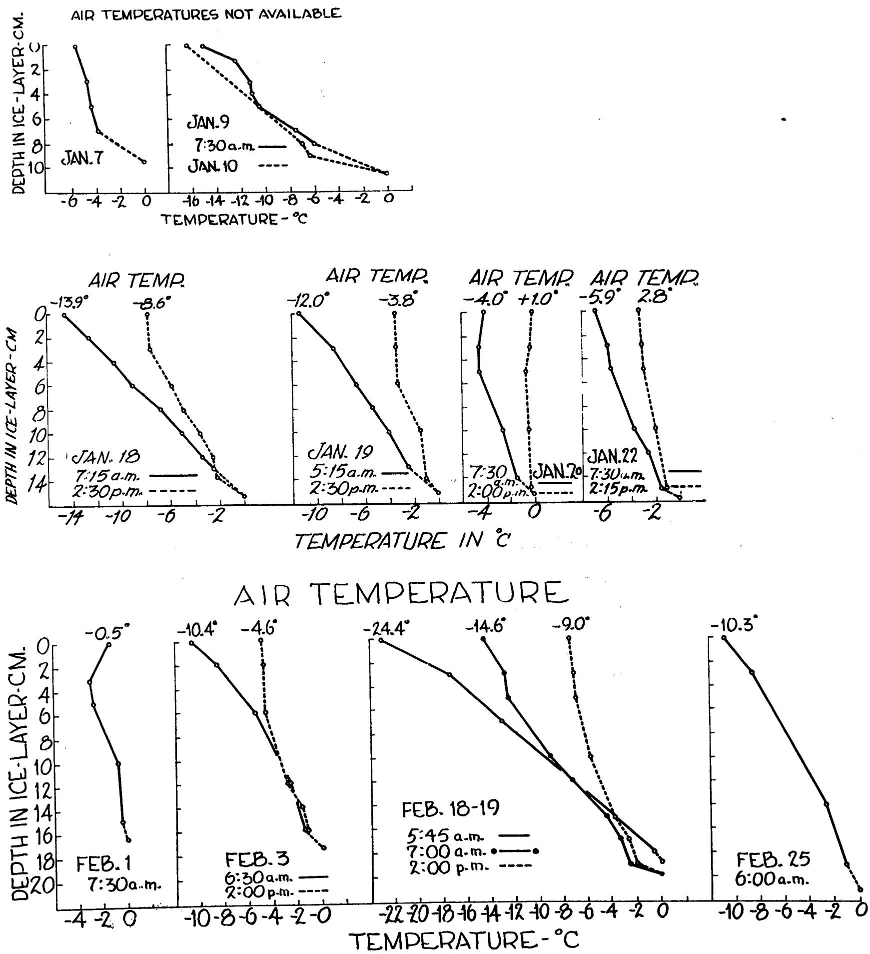

FIGURE 44. Temperatures within the ice-layer on various dates during the winter of 1902–1903. Associated air-temperatures are also shown.

cury rested the bulb of the thermometer. Thus the bulb could be brought into close thermal contact with the ice.

In the winter of 1903 observations were made with this instrument by Mr. Warren D. Smith, then a graduate student at the University of Wisconsin. Holes of different depths were bored into the ice by means of a long-stemmed auger, of such diameter that the wooden case of the thermometer could just slip into them. Thus the temperatures of the ice could be determined at different distances from the surface. The work was not an easy one nor was the instrument suited to give very precise results. It is impossible to make close contact with different strata of ice so that the observer is sure that his instrument records the exact temperature of that stratum. The results must therefore be regarded as approximate only, but they are not without value, especially since no other observations of the kind have come to my notice. The results obtained are given in Fig. 44; from them, the following general conclusions may be drawn:

1. The temperature of the surface of the ice is not essentially different from that of the air, if this is below zero.

2. The temperature of the bottom of the ice is, of course, zero.

3. In general, the temperature curve between the surface and a point near the bottom of the ice is approximately a straight line.

4. During a cold period when the ice is increasing in thickness, the temperature near the bottom of the ice is considerably below zero (see diagram for January 7 and for February 19). In other conditions, the prolongation of the gradient of the curve will meet the zero line at the bottom of the ice.

5. The sun has a considerable diurnal effect in warming the ice, even at low air temperatures. A diurnal increase of 7° or more is recorded at the surface, and of 5° or more at 20 cm. below the surface.

6. The effect of the sun extends throughout the entire thickness of the ice, even when this is 50–60 cm.

7. In periods of warming, the surface of the ice may be warmer than the strata at a greater depth (see diagram for January 20 and February 1).

Change in Thickness of the Ice (1916)

The ice differs much in thickness in different winters, varying with the severity of the weather and with the amount of snow. There is ordinarily a rapid increase after freezing which extends through January, a stationary period during February, followed by a reduction in thickness during March, slow at first but becoming more rapid.

The mean maximum thickness obtained during 12 winters was 50 cm. The greatest thickness was in 1895–1896 (75 cm.) and in 1899 (74 cm.). The least was in 1912–1913 when only 30 cm. were found. In only 4 of the 12 winters did the ice record 50 cm. and in only 2 was it less than 40 cm. Fig. 45 shows the measurements of the ice as taken in several winters. In each winter three periods are well marked, that of increase of thickness, a stationary condition during February and part of March, and a decrease in thickness.

THAWING OF THE ICE (1916)

In 1912 a study was made of the rate of melting of the ice. A hole was bored into the ice and a stick of wood inserted into it. The top of this stick constituted the fixed point. About it was banked snow at first, and later excelsior and burlap in order to prevent

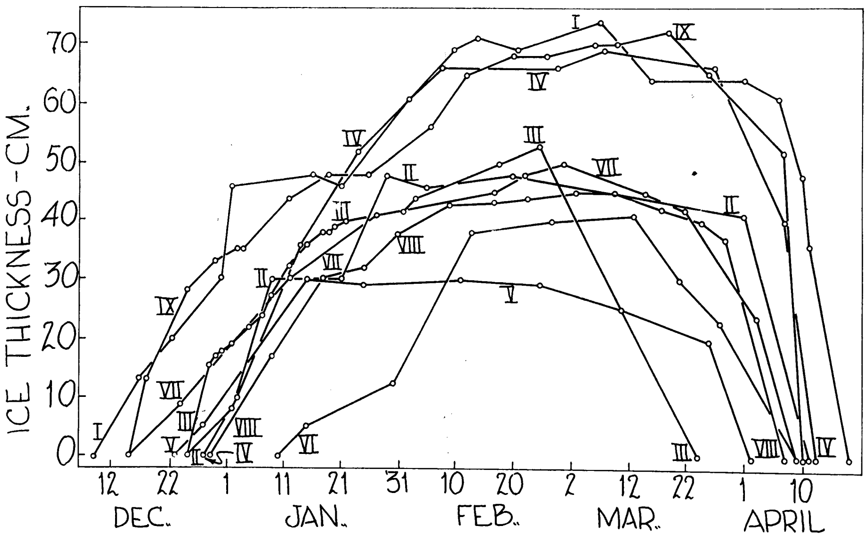

FIGURE 45. Thickness of the ice-layer at various dates during several winters. Years are as follows: I—1898–99; II—1900–01; III—1902–03; IV—1911–12; V—1912–13; VI—1913–14; VII—1914–15; VIII—1915–16; IX—1916–17.

melting of the ice around it. Some 2.5 m. from this stick small holes were cut through the ice. By means of a straight-edge level and calibrated rod, the vertical distance was measured from the top of the stick to the upper and under surfaces of the ice at the holes. The results are shown in Fig. 46. The ice was some 54 cm. thick when the experiment began on March 28 and did not change essentially until after April 2. There was noted on that date, an apparent downward movement of both surfaces, as compared with March 29. But this was probably apparent only, and the condition was doubtless the same on that date as earlier. Then followed a rapid thaw, so that on the 6th of April, the thickness was reduced to about 24 cm., a loss of 30 cm. Of this loss about 1 cm. apparently came from melting from the bottom of the ice and 29 cm. from the top. Two days later the thickness was reduced to about 20 cm., the loss being almost wholly from the top. By this time the ice had become wholly converted into crystals and was unsafe. Besides, the weight of unmelted ice about the stick that formed the fixed point became too great for the weakened ice to support and it began to sink. The experiment was therefore closed.

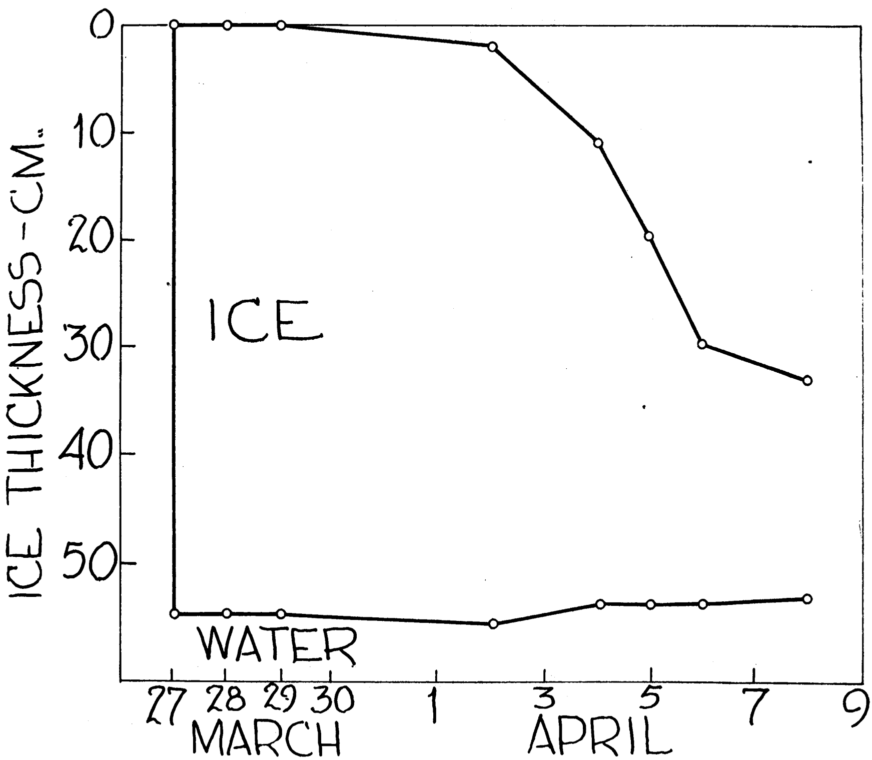

FIGURE 46. Location of the upper and lower surfaces of the ice-layer, April, 1912.

So far as one observation warrants conclusions, the melting of the ice takes place practically from the upper surface, very slightly if at all from the lower surface.

In each year the general story of the melting of the ice is similar to that of 1912 with variations such as naturally follow from the weather. Every year the ice becomes converted into crystals which extend throughout the entire thickness of the ice, and are wholly loosened from each other before the ice breaks up. It is possible to go out on the ice even after the crystals are loosened if they are still over 20 cm. long. But as they shorten by melting at the top, the ice rapidly becomes unsafe and may lie for days in this condition, waiting for a strong wind to shatter the remaining adhesion of the crystals.

The ice melts first in the shallow water of the edge of the lake and in bays, giving the wind and waves an opportunity to attack the ice. Sometimes the ice is partly broken up and is moved apart in large floes. In other years it remains substantially entire until a strong hot south wind breaks it up, completely and finally into a mush of crystals which rapidly melt, attacked on all sides by the warm water as soon as they fall apart.

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PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. NO. 38. RUBIACEAE—MADDER FAMILY

EMIL K. URBAN[1] and HUGH H. ILTIS[2]
Herbarium of the University of Wisconsin

The following notes and maps are based on specimens in the herbaria of the University of Wisconsin at Madison, the Milwaukee Public Museum, the University of Minnesota, and the Chicago Natural History Museum. A dot represents the actual locality where a specimen was collected, the triangles county records without definite location.[3]

Grateful acknowledgement is made to Albert M. Fuller, curator of the Milwaukee Public Museum herbarium, and to Gerald B. Ownbey, curator of the University of Minnesota herbarium, for the loan of their Wisconsin Rubiaceae, to E. E. Terrell of Guilford College, North Carolina, for critical advice and checking of certain identifications in *Houstonia,* and to James Zimmerman and John Thomson, both of the University of Wisconsin, for reading the manuscript and for helpful suggestions.

KEY TO THE GENERA OF RUBIACEAE IN WISCONSIN

A. Leaves opposite (or rarely in 3's in *Cephalanthus*), greatly exceeding the stipules.

B. Flowers terminal, stalked, cymose or in heads, the stipules inconspicuous.

C. Shrubs with woody stems; flowers and fruits in dense globose heads, the peduncles 3–8 cm. long; leaves lanceolate to ovate or oblong, 8–15 cm. wide .... 1. *Cephalanthus*

CC. Small herbs; flowers in cymes or pairs or solitary; leaves 0.2–2.5 cm. wide.

D. Plants creeping, with evergreen, round ovate, truncate or cordate, petioled leaves; fruit a red berry composed of the fused ovaries and hypanthia of the paired, whitish flowers .... 2. *Mitchella*

DD. Plants erect, or ascending; leaves not evergreen, ovate, oblong, or lanceolate; fruit a dry capsule splitting length-wise at maturity; flowers singly on terminal peduncles or in terminal cymes, blue, lilac, or rarely whitish .... 3. *Houstonia*

BB. Flowers in axillary glomerules, sessile or subsessile; herbs with conspicuous bristle-like, filiform stipules .... 4. *Diodia*

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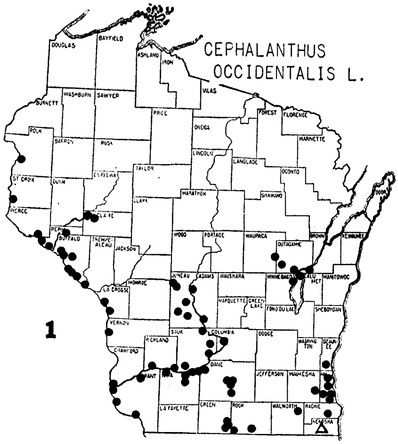
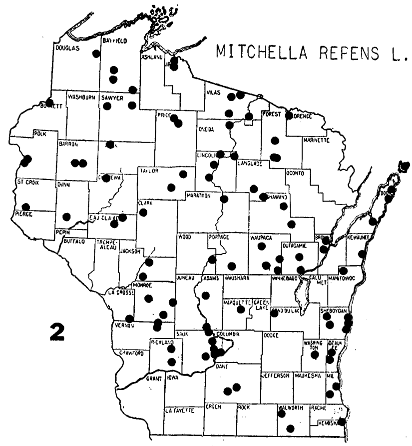
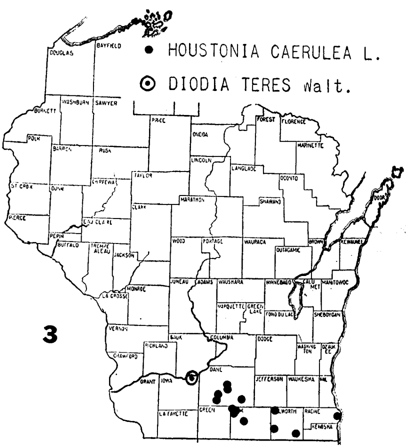
[1] Dept. of Zoology, Univ. of Kansas, Lawrence, Kansas.
[2] Curator of the Herbarium, Dept. of Botany, Univ. of Wisconsin, Madison, Wisc.
[3] Many of the specimens on which this report is based were collected on field trips supported by grants from the Wisconsin Alumni Research Foundation.


CEPHALANTHUS
OCCIDENTALIS L.

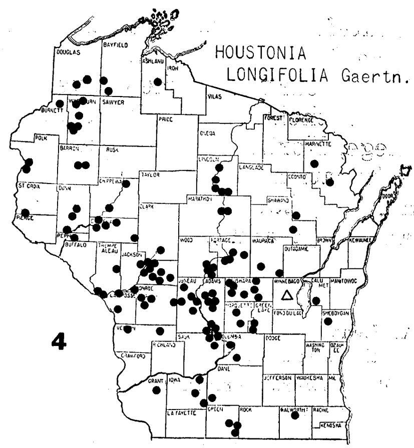
1


MITCHELLA REPENS L.

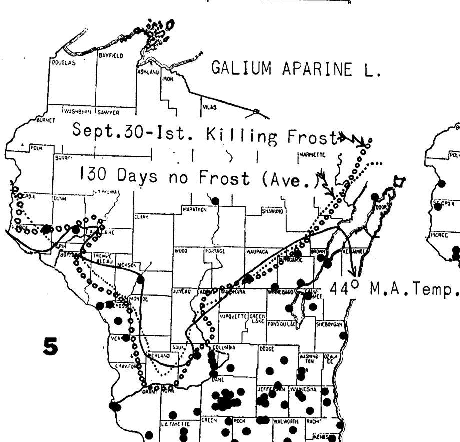
2


● HOUSTONIA CAERULEA L.
⊙ DIODIA TERES Walt.

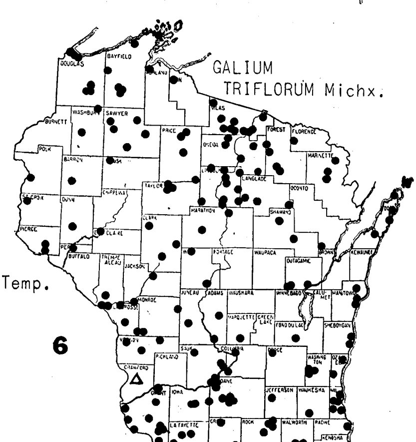
3


HOUSTONIA
LONGIFOLIA Gaertn.

4


GALIUM APARINE L.
Sept.30-Ist. Killing Frost
130 Days no Frost (Ave.)
44° M.A.Temp.

5


GALIUM
TRIFLORUM Michx.

6

AA. Leaves whorled, 4–8 at a node (i.e. the stipules foliaceous and like the leaves).

E. Flowers in terminal heads, subtended by an involucre of about 8 lanceolate leaves fused at the base; sepals triangular .... 5. *Sherardia*

EE. Flowers in open panicles or cymes without an involucre; sepals obsolete or lacking .... 6. *Galium*

1. CEPHALANTHUS L.

1. C. OCCIDENTALIS L. Buttonbush. Map 1.

Woody shrubs of wet, low places, such as marshes, swamps, sloughs, open roadside ditches, and margins of ponds, streams and rivers, sometimes in deciduous river bottom woods, widespread throughout the southern counties, especially along the Wisconsin and Mississippi Rivers, and locally northward; flowering from late June through August.

2. MITCHELLA L.

2. M. REPENS L. Partridge Berry. Map 2.

Throughout most of Wisconsin, except in the southwestern corner of the state; in various habitats, of both moist and dry deciduous woods, such as maple-oak, maple-basswood-yellow birch, beech, and maple-hemlock, in pine woods *(P. strobus)*, often in rich woods in ravines, occasionally on the edge of tamarack *(Larix)* and white cedar *(Thuja)* swamps, and on sandstone cliffs and outcrops; flowering from May through July.

The flowers in this species are of two types, either with long-exserted styles and very short-filamented stamens, or with long-exserted stamens and short, included styles. Of the flowering specimens we studied, about 60% were of the former, the remainder of the latter type.

3. HOUSTONIA L.

Key to Species

a. Annual (or rarely perennial ?); stems slender, 6–16 cm. tall; flowers singly on long peduncles, sky-blue to white, with yellow centers, the corolla salverform; stamens included; southern Wisconsin .... 1. *H. caerulea*

aa. Perennial; stems firm, 8–23 cm. tall; flowers short-pediceled, several in each cyme, light purple throughout, rarely white; corolla funnelform; stamens exserted .... 2. *H. longifolia*

1. H. CAERULEA L. Bluets, Innocence. Map 3.

In moist meadows, fields, and open woods in the southeastern counties, northward to Dane County; flowering from late April to June.

2. H. LONGIFOLIA Gaertn. Map 4.

Houstonia purpurea var. *longifolia* (Gaertn.) Gray.

Widespread in the state, particularly abundant in the central plain or lowland (of Cambrian sandstones; Martin, 1932), in the sandy areas of Glacial Lake Wisconsin in the central part of the state, lacking, with few exceptions, from most of the area of the pre-Cambrian rocks in north-central Wisconsin and from the south-eastern corner of the state; occurring in a great variety of acid habitats: on dry, often sandy woods and cliffs, in jack pine-aspen, on juniper glades (e.g. Observatory Hill, Marquette Co.—a quartzite monadnock), in mesic and sandy prairies, sedge meadows, open sandy fields, and rarely in tamarack swamps. According to Dr. E. E. Terrell (personal communication), this is the only species of the *H. purpurea* complex occurring in Wisconsin; flowering from early June through August (October).

4. DIODIA L.

4. D. TERES Walt. var. SETIFERA Fern. and Grisc. Buttonweed. Map 3.

Occurring in Wisconsin only on the old sandy river terraces of the Wisconsin River north of Arena in Iowa County, where it is locally abundant; flowering from July through September.

5. SHERARDIA L.

5. S. ARVENSIS L. Field-Madder.

Introduced from Eurasia; collected once in a sandy field in Sheboygan County, July 1903, by Chas. Goessl.

6. GALIUM L.

A. Fruit or ovary more or less bristly or hairy, the hairs often hooked at the tip.
  B. Principal leaves in whorls of 5–8, the blades cuspidate at the apex; stems, when mature, weak and reclining; stem angles, leaf margins, and midrib (beneath) more or less scabrous.
    C. Leaves 2–4 mm. broad, about 10 times as long, linear-oblanceolate, usually in whorls of 6–8; cilia on leaf margins divergent or retrorse; stems harshly retrorse-scabrous; annual .... 1. *G. aparine*
    CC. Leaves 5–12 mm. broad, 2–4 times as long, elliptic, usually in whorls of 6, the midrib on the under side strongly retrorse scabrous; cilia on leaf margins ascending; stems essentially glabrous or with few to many divergent or slightly retrorse scabrous hairs; perennial .... 2. *G. triflorum*
  BB. Principal leaves in 4's, the blades pointed to blunt at the apex, not cuspidate; stems erect or ascending, not retrorsely scabrous on the angles.

D. Inflorescences in compact, many-flowered panicles; flowers showy, white, pediceled .... 3. *G. boreale*

DD. Inflorescences open, each of the few peduncles with 2–4(–5), distant, unilateral, sessile, greenish or purplish flowers.

E. Leaves ovate to oblong, usually widest toward the middle, broadly acute to obtuse; major stem leaves 24–42(–52) mm. long; corolla greenish, hairy outside .... 4. *G. circaezans*

EE. Leaves lanceolate, broadest near the base, acute to acuminate; major stem leaves (38–)45–72 mm. long; corolla yellowish to purplish, glabrous outside .... 5. *G. lanceolatum*

AA. Fruit or ovary glabrous or tuberculate, not bristly or hairy.

F. Flowers yellow, in rather dense showy panicles; stems minutely puberulent, erect; leaves linear, mostly in whorls of 8; introduced species, rare in Wisconsin .... 6. *G. verum*

FF. Flowers white.

G. Stems erect or strongly ascending; neither leaves nor stems retrorsely scabrous, rarely rough to touch; leaves with 3 nerves, in whorls of 4; common native species .... 3. *G. boreale*

GG. Stems usually slender and weak, either erect, loosely ascending, reclining on or supported by other plants, often ± matted, the leaves or stems either glabrous or scabrous.

H. Leaves acute or broadly acuminate, sharply bristle-tipped or mucronate (the bristle sometimes very small), 5–9 at a node.

I. Leaves with smooth or usually upwardly scabrous margins, (5–)6(–9) at a node, linear-elliptic, 2–3 mm. wide; stems smooth or minutely scabrous, less than 4 dm. high; slender, clustered plants of woods .... 7. *G. concinnum*

II. Margin of leaves and stems retrorse-scabrous; leaves (5–)6 at a node, oblanceolate to obovate, 3–6 mm. wide; very rough, rather rank perennials of wet habitats .... 8. *G. asprellum*

HH. Leaves obtuse or rounded at tip, without a sharp terminal point or bristle, 4–5(–6) at a node; plants of wet or damp habitats.

J. Corolla 4-lobed, 2–4 mm. in diam. at anthesis, the lobes longer than wide; nodes, under magnification, more or less conspicuously hairy, the hairs (cilia) on the leaf-margin never sharply retrorse, but more or less divergent, and essentially at right angles to the margin.

K. Leaves 3–6 mm. wide, 10–22 mm. long, divergent to ascending, flat; mature carpels each 2–3 mm. in diam.... 9. *G. obtusum*

KK. Leaves 1–2 mm. wide, 5–10(–15) mm. long, often (with age) reflexed and with down-rolled margins; mature carpels each 1.0–1.7 mm. in diam. .... 10. *G. labradoricum*

JJ. Corollas predominantly 3-lobed (occasionally an individual flower 4-lobed), 0.8–1.5 (–2.2) mm. in diam. at anthesis, the lobes triangular and about as long as wide; nodes glabrous or essentially so; hairs on *leaf margin* (not upper surface) retrorse.

L. Pedicels (6–)10–20 mm. long, *very slender*, when *mature curved at the tip, minutely scabrous;* flowers 1–2 at a node, or in 3's when at the tip of a branch, 1.0–1.5 mm. in diam. ....11. *G. trifidum*

LL. Pedicels 1–5(–8) mm. long, stiff and usually straight, *glabrous.*

M. Flowers and fruits chiefly in 2's and 3's at the end of short lateral branches, the fruiting pedicels of about equal length, strongly diverging, 2–5 mm. long (or 1–2 longer pedicels occasionally in the axils of the leaves of the main stem); larger leaves 10–15 mm. long; flowers 1.4–2.0 mm. in diam., common .... 12. *G. tinctorium*

MM. Flowers and fruits usually 1–2 in the axils of the leaves, the pedicels 1–4(–?) mm. long, or 2 (rarely 3) at the end of lateral branches, with one flower usually subsessile and one on a much longer pedicel; plants mat-forming, usually very leafy with very short internodes, the leaves small, 5–10 mm. long; flowers 0.7–1.1 mm. in diam., rare.. 13. *G. brevipes*

1. G. APARINE L. Cleavers, Goosegrass. Map 5.

In shady, rich woods (e.g. mature, undisturbed *Acer saccharum* woods at Spring Grove; Abraham's Woods, Albany, both Green Co., there giving every appearance of being indigenous), thickets, along roadsides, under hedges and in dumps, etc., often weedy, throughout all of the southern counties, and only locally northward, being apparently sharply delimited by climatic factors related to temperature. Isotherms corresponding roughly to the northern limit of this species include the ones of the 44° F. mean annual temperature (Martin, 1932), the average number of days without frost (i.e. 130), and the first killing frost of the fall on Sept. 30 (U.S.D.A., 1941).

G. aparine is a winter-annual, the 2–8″ long autumn shoots common in late September and early October. Their dark green leaves, bristly above, differ in appearance from the spring shoots: they are shorter and broader, and occur *6* at a node throughout, whereas the spring leaves are long and slender, and occur usually *8* per node.

The fact that this is a winter-annual might possibly explain its peculiar distribution. Since the plant has very slender roots and no storage organs whatever, it would evidently be dependent solely on photosynthesis to survive the winter. As a result of lower temperatures, the more persistent snows of Northern Wisconsin would prevent sunshine reaching the leaves for months and therefore plant survival would be difficult.

2. G. TRIFLORUM Michx. Sweet-scented Bedstraw. Map 6.

Widely distributed and very common throughout the state in rich low or mesic woods and thickets; flowering from June to August.

Similar to *G. aparine,* but a perennial with stems not very rough to the touch or smooth, much broader elliptic leaves always in whorls of 6, and much smaller fruits.

3. G. BOREALE L. ssp. SEPTENTRIONALIS (Roem. and Schult.) Iltis. Northern Bedstraw. Map 7.

Galium septentrionalis Roem. and Schult. Syst. Veg. 3:253. 1818. *Galium boreale* L. of all American authors, including its varieties, not *G. boreale* L. *sensu stricto (G.b.* ssp. *boreale),* which is Eurasian.

A very common species, the white flowers often showy, which occurs in low and mesic prairies, southern and northern hardwood forests and in a variety of other habitats, showing its best growth in those that are open.

In Wisconsin, as elsewhere, this species is very variable. (Leyendecker 1941a). Fernald (1950), under *G. boreale (sensu lato),* classifies the varieties using names originally applied to their European homologues in ssp. *boreale:*[1]

a. Fruit hairy.
b. Fruit covered with long straight hairs ...."Var. *boreale* (typical)"
bb. Fruit covered with short appressed or incurving hairs .... "Var. *intermedium*"
aa. Fruit glabrous or glabrate .... "Var. *hyssopifolium*"

"*G. boreale* (typical)". Mostly in the western part of the state, in oak openings and less mesic woods" (Terrell, 1954).

"Var. *intermedium* DC." Distributed quite commonly throughout most of the state except the northcentral area of pre-cambrian rocks, "in prairies, oak openings, and roadsides" (Terrell, l.c.). This appears to us to be by far the most common form.

"Var. *hyssopifolium* (Hoffm.) DC." Sparsely distributed mainly in the southern half of the state apparently "growing in all habitats" (Terrell l.c.).

Terrell (l.c.), who studied the variability of this species in Wisconsin, showed that the varieties intergrade strongly and that here they are of little taxonomic value. A cursory examination of the herbarium specimens collected in Wisconsin shows that between the glabrous (25 collections) and the hairy extremes (27 collections) there are all possible intermediate types (92 collections).

4. G. CIRCEAZANS Michx. var. HYPOMALACUM Fern. Wild Licorice. Map 8.

Very locally distributed through the southern counties in rich woods; flowering from June through July.

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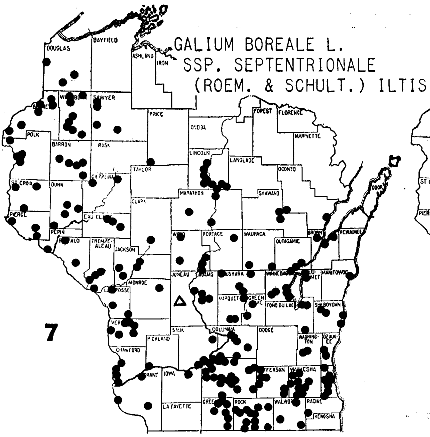
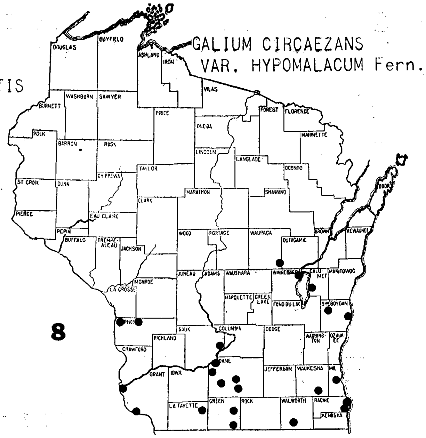
[1] The junior author recently pointed out (Iltis, 1957) that the nomenclature and typification of the varieties of ssp. *septentrionalis* presents great difficulties, as the whereabouts of the type of *G. septentrionalis* (*G. boreale* Pursh, *non* L.) is not known. Urschler's (1955) assumption that *G. septentrionale* is equivalent to the long-haired "*G. boreale* var. *typicum* Fernald" is unwarranted by the inadequate description of Roemer and Schultes, and it is impossible to say at present to which of the two pubescence forms the type belongs. The types, not only of *G. septentrionalis*, but also of the Japanese and Russian varieties of this complex, will have to be studied before this problem can be solved.


GALIUM BOREALE L.
SSP. SEPTENTRIONALE
(ROEM. & SCHULT.) ILTIS

7


GALIUM CIRCAEZANS
VAR. HYPOMALACUM Fern.

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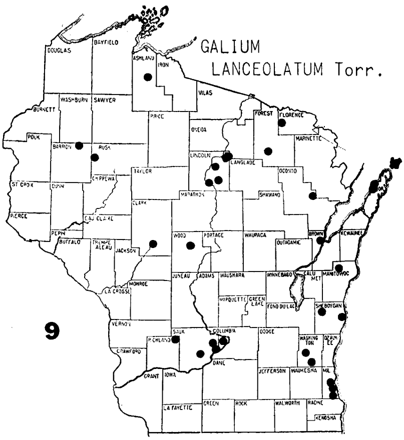
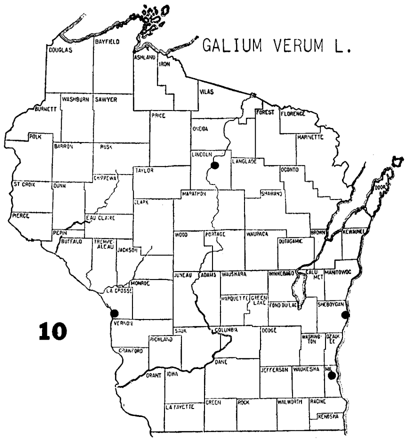

GALIUM
LANCEOLATUM Torr.

9


GALIUM VERUM L.

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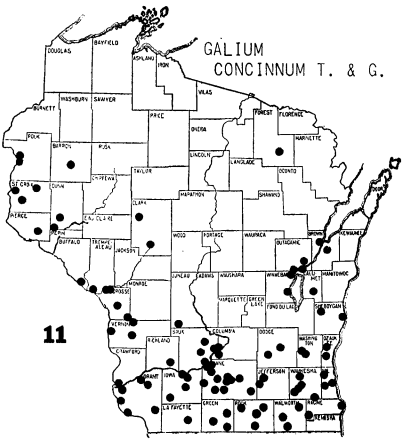
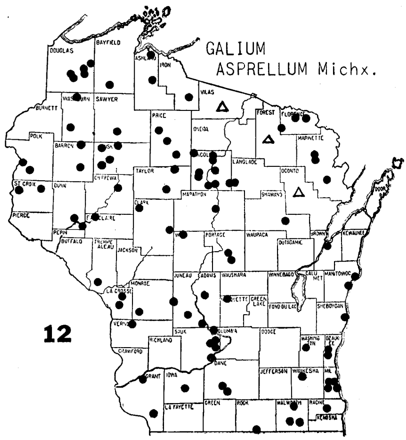

GALIUM
CONCINNUM T. & G.

11


GALIUM
ASPRELLUM Michx.

12

5. G. LANCEOLATUM Torr. Wild Licorice. Map 9.

Rather uncommon and local, occurring in dry or moist rich woods; flowering in June and July.

Closely related to *G. circaezans,* with which it may grow (e.g. in Parfrey's Glen, Sauk Co.), but differing in addition to the vegetative characters of the key by being nearly glabrous, *G. circaezans* being more or less pubescent. Some collections of these two species are nearly indistinguishable as far as leaf shape is concerned.

6. G. VERUM L. Yellow Bedstraw. Map 10.

Introduced from Eurasia, in dry fields and roadsides; flowering from June to early September.

7. G. CONCINNUM T. & G. Pretty Bedstraw; Shining Bedstraw. Map 11.

A delicate species common and characteristic in dry woods and thickets throughout most of the southern counties and locally northward; flowering from June to early August. The leaves occur most commonly in whorls of 6, though an occasional specimen *(e.g. Iltis 5949)* has 7–9 leaves at some of the nodes of the main stem.

8. G. ASPRELLUM Michx. Rough Bedstraw. Map 12.

In low grounds, moist rich woods, swamps, wet prairies and sedge meadows, and damp thickets, widespread and common throughout all the counties of the state; flowering from June through August.

Easily recognized by the 6 relatively broad leaves per node, its roughness (leaf margin cilia retrorse!) and large size, some plants trailing for almost two yards over surrounding vegetation.

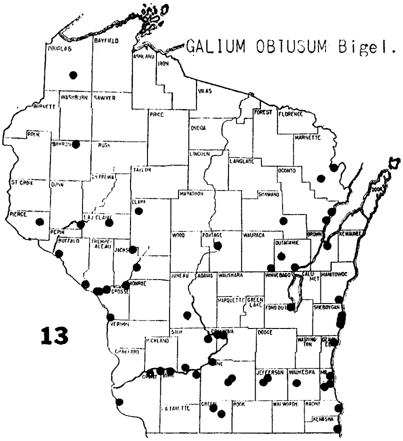
9. G. OBTUSUM Bigel. var. RAMOSUM Gleason. Stiff Marsh Bedstraw. Map 13.

In moist ground, such as low woods, swamps, low prairies and wet shores, locally throughout the southern half of the state, north to Barron, Clark, and Brown Counties; flowering from late May to July.

The 4-lobed corolla, hairy nodes, glabrous stems (very rarely scabrous), scabrous midribs, cilia on leaf margins which ascend or are at right angles to the rather broad blades, and the large fruits identify this plant. In herbarium material the leaves are commonly ascending, whereas in the closely related *G. labradoricum* the leaves are reflexed.

10. G. LABRADORICUM Wieg. Labrador Marsh Bedstraw. Map 14.

Locally abundant in low prairies and sedge meadows, mossy thickets and moist woods, in Wisconsin close to the southwestern



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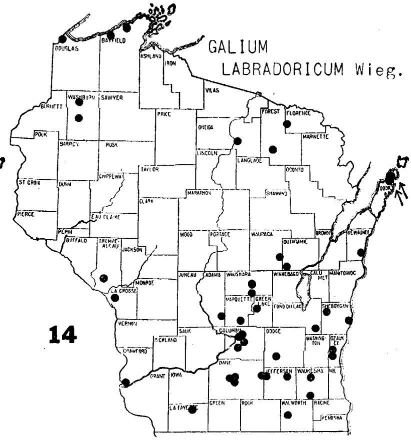

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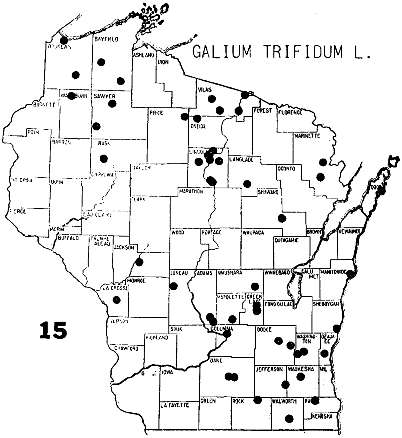

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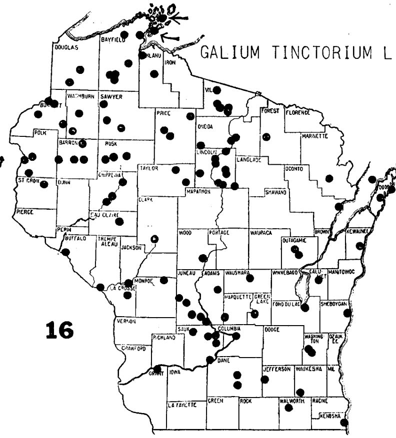

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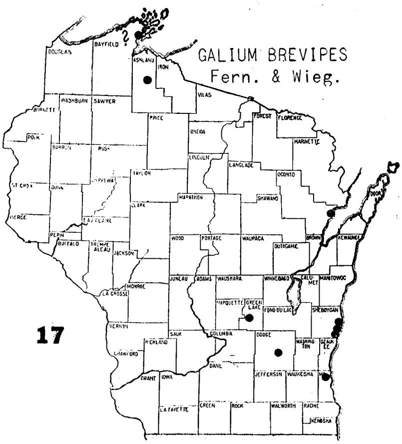

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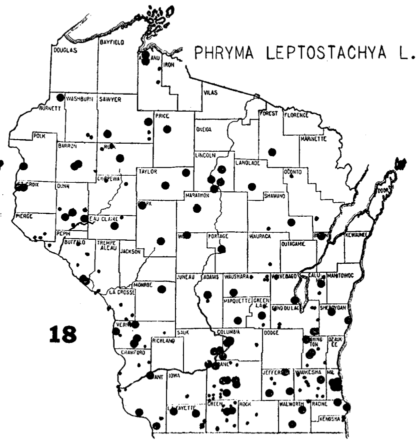

18

edge of its range (cf. map in Iltis, 1957); flowering from late May to early August.

This and the following three species are of similar habit and habitat and are often distinguishable only with difficulty. *G. labradoricum* is the most easily recognizable taxon of this group by having consistently *4-lobed corollas,* (2.0–)3.0(–4.0) mm. in diam. at anthesis, rather strongly *deflexed* small leaves, often inrolled on drying, and a pubescence that is similar to the closely related *G. obtusum,* i.e., short straight, rather soft hairs on the nodes, leaf margin, and rarely on the midrib, that diverge at essentially right angles to the leaf margin, with the latter therefore not retrorsely scabrous. The top surface of the leaf is quite glabrous. Contrary to Gleason (1952) and Fernald (1950) the stems in the Wisconsin material, as well as that of other states, are almost always minutely and retrorsely scabrous on the angles, particularly in the older, lower portions. *Galium labradoricum* flowers earlier than the next three species.

11. G. TRIFIDUM L. Small Bedstraw. Map 15.

Locally abundant in swamps, wet shores, sedge meadows, etc., often occurring together with closely allied species such as *G. tinctorium* and *G. brevipes* as well as with *G. labradoricum;* flowering from late July to early September. See comments following species 13.

12. G. TINCTORIUM L. Map 16.

G. claytoni Michx.

In marsh lands, swamps, sedge meadows and other damp places, quite common throughout most of Wisconsin; flowering from June to early September. See comments following species 13.

13. G. BREVIPES Fern. and Wieg. Map 17.

This species, which prefers calcareous swamps, wet shores, mossy swales behind dunes along Lake Michigan, and boggy soils, is rare in Wisconsin (cf. map and comments in Iltis, 1957); flowering from June to September.

NOTES ON G. TRIFIDUM, G. TINCTORIUM AND G. BREVIPES

As has been pointed out by Wiegand (1897), these are very closely related taxa; Hulten (1949: 1439) states that despite much work by several authors "to the clarification of . . . (this) . . . complex question . . . the conditions within the group are far from clear, and a new treatment . . . is highly desirable. To what extent . . . (these) . . . are really well defined species, or should sooner be regarded as races with transitions joining them, does not at present seem to be clear."

In Wisconsin, at least, these entities appear to be reasonably distinct, though mainly on rather small, quantitative characters. Two species *(G. tinctorium, G. trifidum)* are quite common and readily distinguishable in the field (which is not always true of herbarium material). The junior author has seen them growing side by side (e.g. South of Portage, Columbia County), in exactly the same habitat and in great abundance, without any intermediates whatever, so that it would appear that they are genetically isolated. Aside from the key characters (long, curved, slender, scabrous pedicels), *G. trifidum* in the field is a more slender-stemmed plant with longer internodes and fewer, generally narrower leaves, which on the main stems, though usually in 4's, may occur in 5's and 6's at a node, but not as frequently as in *G. tinctorium.* The leaves, furthermore, have rather distantly spaced marginal hairs (usually 5 or less per mm.), while in *G. tinctorium* the leaf margin is densely scabrous (6–10 hairs per mm. or more), with the hair bases sometimes almost touching. The flowers of *G. trifidum* are smaller (by about 0.5 mm.), while the fruits appear to be somewhat larger than those of *G. tinctorium* (cf. Gleason (1952), who states the reverse!).

Galium tinctorium, on the other hand, can be told by the many short lateral branches, each bearing terminally 2–3 *strongly divergent* (each by ca. 90°) short, stiff, *glabrous pedicels of about equal length;* only occasionally does one find single, long pedicels in the axils of the main stem, which, in contrast to those of *G. trifidum,* are straight and glabrous.

The rare *Galium brevipes,* a northern taxon occurring in Wisconsin in habitats with cool summers, appears to us to be most closely allied to *G. tinctorium.* In northeastern Minnesota the two species appear to intergrade. Therefore, it is possible that *G. brevipes* may well be nothing but a subarctic or a depauperate form of *G. tinctorium,* differing from it mainly in the weaker stems and smaller size, in the tendency to form intricately branched mats (though this appears to be true of all three species depending on whether they grow in tall grass or in the open on moss), and in the shorter pedicels and branch internodes (5–15 mm. long on lateral branches). The fruits are either solitary or in 2's in the axils of the main stem leaves on up to 6 mm. long pedicels, or are borne terminally, either on short lateral branches or at the end of a main shoot. These terminal fruits are usually in 2's (rarely 1's or 3's) of which one is *nearly sessile* while the *other is on a 2–5 mm. long pedicel much surpassing the first.* In plants of this species one does occasionally find a fruit with a 10 mm. long "pedicel" simulating *G. trifidum.* However, on closer examination this "pedicel" will have a scar near the fruit, the place where a subtending leaf has fallen off—the pedicel therefore is to be measured from the scar to the fruit; what is beneath the scar is a lateral branch.

The flowers of *G. brevipes* are usually much smaller than either those of the other two species, though of exactly the same shape. While the scabrosity is a little less pronounced, all Wisconsin specimens are scabrous on the stem, the lower half of the midrib and usually on the leaf margin (except in very young leaves).

The junior author, in company with Robert Koeppen, has found *G. brevipes* growing in abundance, side by side with *G. trifidum,* in a mossy, moist swale behind the first dune of Lake Michigan, east of Cedar Grove, Sheboygan County. No intermediates were found, and in the field the slenderness of *G. trifidum* made a distinction from the more robust *G. brevipes* easy. It may be worth noting, that, despite statements in floras (e.g. Gleason, 1952), *G. brevipes* has the principal leaves in 5's and 6's, except in depauperate shoots.

Without flowers and fruits (i.e., without good material) *it is impossible,* in our estimation, *to separate the 3 species* of this group *by vegetative characters.* The apparent vegetative differences mentioned in manuals may be trends that would lend themselves to statistical analysis but cannot be used in keys. The junior author has at present plants of all three species growing in the Botany Department greenhouse, the sterile, young shoots of which are indistinguishable from one another.

NOTES REGARDING *GALIUM BRANDEGEI* A. GRAY

Gleason (1952) considers *G. brevipes* identical with *G. brandegei,* the latter a species described from the western mountains. It seems to us that the material we have seen of the latter is not identical with *G. brevipes* as it occurs in Wisconsin. *G. brandegei* seems to be a much smaller, less branched species, with much larger fruits, and generally more glabrous stems and leaves (though Fernald's "glabrous throughout" does not always hold true—e.g., *Rydberg & Carlton 7629* (MIN) from Utah, which has quite scabrous stems).

An over-all monographic study of this complex is badly needed, since the taxa discussed above, while distinct in Wisconsin, appear to intergrade in other parts of their range, particularly in the Rocky Mountains and the Western United States, where, furthermore, they do not resemble our plants too closely.

GALIUM PALUSTRE L. IN WISCONSIN?

Fernald (1950) and Gleason (1952) report this species in Wisconsin. However, after comparing all specimens available to us, none were found to have the distinguishing characters of *G. palustre:* excavated fruit, dichotomous cymes, pedicels horizontally spreading, scabrous stem angles, and the characteristic long internodes. Jones and Fuller (1955) do not list the species for Illinois. There are no specimens of *G. palustre* from Wisconsin in the Gray Herbarium (personal letter of Reed Rollins).

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PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. NO. 39. PHRYMACEAE—LOPSEED FAMILY

HUGH H. ILTIS
Herbarium of the University of Wisconsin

The following notes and maps are based on specimens in the herbaria of the University of Wisconsin at Madison, the Milwaukee Public Museum, and the University of Minnesota. A large dot represents the actual locality where a specimen was collected, a small dot a sight record made by ecologists of the University of Wisconsin. For the use of their files, I express my appreciation.

1. PHRYMA

1. PHRYMA LEPTOSTACHYA L. Lopseed. Map 18.

Shady, moist, deciduous woods, Hemlock- and Pine-Hardwoods, Southern Hardwoods, and Oak Openings, throughout Wisconsin, especially common in the southern half of the state; flowering in July, and fruiting from end of July through October.

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. NO. 40. ASCLEPIADACEAE—MILKWEED FAMILY

GOTTLIEB K. NOAMESI and HUGH H. ILTIS
Herbarium of the University of Wisconsin

The nomenclature and arrangement of taxonomic units follow "The North American species of Asclepias" by R. E. Woodson, Jr. (1954), except for *A. lanuginosa* Nutt., where Jones' (1955) treatment is used.

The maps and habitat notes were compiled from material in the herbaria of the Universities of Wisconsin and Minnesota, and of the Milwaukee Public Museum; to their curators, Gerald B. Ownbey and Albert M. Fuller, our thanks are due for the loan of specimens. A limited amount of field work was carried out during the summer of 1956.[1]

Works useful in writing the keys included, in addition to Woodson's (1954) monograph, Deam's "Flora of Indiana" (1940), and Nicolson and Russell, "The Genus Asclepias in Iowa" (1955).

Grateful acknowledgement is made to James H. Zimmerman for his criticisms and suggestions regarding the keys.

KEY TO GENERA

a. Stem erect or ascending, not climbing; inflorescences umbellate; flowers with a crown of 5 hoods, the petals reflexed .... I. *Asclepias*
aa. Stem twining; inflorescences cymose; flowers with a 5-lobed disc between the corona and the petals, these rotate, dark purple; rare, introduced.... .... II. *Cynanchum*

I ASCLEPIAS L. MILKWEED

KEY TO SPECIES

A. Orifice of hoods appressed at apex to antherhead; hoods without any horns, subequal or shorter than antherhead; flowers greenish-yellow; leaves linear-lanceolate to lanceolate or oblong, 5–25 (–35) mm. wide. (Subgenus *Acerates*).
B. Inflorescence terminal and solitary on each stem; stems and underside of leaves more or less densely pilose, the hairs divergent, 1–3 mm. long; stems 10–20 (–25) cm. tall .... 13. *A. lanuginosa*
BB. Inflorescence lateral 2–13 (rarely one) on each stem; stems and leaves pubescent, glabrescent or glabrous, the hairs appressed, 1 mm. or less long; stems (15–) 30–75 cm. tall.

[1] Many of the specimens on which this report is based were collected on field trips supported by grants from the Wisconsin Alumni Research Foundation.

C. Leaves few, (10–) 15–25 (–30) on each stem, linear lanceolate to lanceolate or ovate-oblong, (8–) 12–26 (–35) mm. wide; pubescence of soft, crisp hairs; corona sessile . . . . 12. *A. viridiflora*

CC. Leaves many, 30–80 (rarely fewer) on each stem, linear to linear-lanceolate, 5–14 mm. wide; pubescence of short, rough hairs; corona short-stalked . . . . 11. *A. hirtella*

AA. Hoods freely open above, each with a horn within, the hood equal to or longer than the antherhead (shorter sometimes in No. 4); flowers of various colors; leaves various, 2–100 mm. wide.

D. Leaves narrowly linear, 2 mm. or less wide, chiefly whorled in 3's or 4's, with a few alternate; flowers whitish-green to very pale yellow. . . . . 2. *A. verticillata*

DD. Leaves 10 mm. or more wide, alternate or opposite.

E. Leaves all opposite.

F. Leaves glabrous beneath (subglabrous with a few scattered hairs in No. 4, or along veins in No. 1).

G. Inflorescence terminal and solitary, the peduncle (usually) much surpassing uppermost leaf.

H. Horns much surpassing hoods; leaves deeply cordate at base, obtuse to rounded or emarginate at apex, broadly ovate or oblong, with crisped and undulate margins . . . . 5. *A. amplexicaulis*

HH. Horns inclosed in hoods; leaves with truncate to rounded base, not clasping the apex acute, ovate to lanceolate, with flat margins . . . . 8. *A. meadii*

GG. Inflorescences 2–many, lateral and terminal, if solitary and terminal, the peduncle shorter than the uppermost leaf.

I. Leaves subsessile; horns enclosed in hoods; flowers purple. . . . . 9. *A. sullivantii*

II. Leaves petioled; horns surpassing hoods.

J. Flowers white, in several scattered, lax umbels; leaves broadly elliptic, long-acuminate at both ends; plants of woods. . . . . 4. *A. exaltata*

JJ. Flowers pink, the many umbells forming a dense terminal showy corymb; leaves lanceolate, acute to truncate at base; plants of wet, open places . . . . 1. *A. incarnata*

FF. Leaves densely and finely pubescent beneath.

K. Flower yellow or greenish; plants small, 15–40 (–55) cm. high; leaves small, 3–8 cm. long, 2–5 cm. wide . . . . 6. *A. ovalifolia*

KK. Flowers purplish or white; plants large, 50–100 cm. high; leaves large, 10–23 cm. long, 5–9 cm. wide.

L. Flowers dark to light purple; leaves broadly ovate to oblong-elliptic, obtuse to rounded at base; inflorescences dense.

M. Hoods (when spread out) with triangular marginal auricle; petals pubescent outside; uppermost inflorescence lateral. . . . . 7. *A. syriaca*

MM. Hoods without sharp triangular lobe, only broader in the middle; petals glabrous outside; uppermost inflorescence terminal . . . . 10. *A. purpurascens*

LL. Flowers white (flushed with green or purple); leaves broadly elliptic, strongly attenuated to the base from near the middle. Inflorescences lax . . . . 4. *A. exaltata*

EE. Leaves below inflorescence alternate; flowers orange; hoods up to two times longer than the antherhead; inflorescence of several terminal umbels . . . . 3. *A. tuberosa*

SUBGENUS I. ASCLEPIAS

1. A. INCARNATA L. Swamp Milkweed. Map 1.

Represented in Wisconsin by subspecies *incarnata.*

Small pinkish-purple flowers, arranged in a somewhat flat-topped inflorescence of many umbels which are borne at the tips of the many branches. A beautiful showy species of open, wet places such as swamps, shore of lakes and rivers, often in alluvial soil, common throughout the state. Flowering from mid-June to mid-August.

2. A. VERTICILLATA L. Map 2.

Leaves linear-filiform. Flowers whitish, small, 3 mm. across. A very distinct species of dry sandy soils and dry prairies, often weedy on roadsides and pastures, found in the southern half of the state. Flowering from July to early September.

3. A. TUBEROSA L. Butterfly-weed. Map 3.

Represented in Wisconsin, according to Woodson (1954), by subspecies *interior* Woods., with cordate leaf bases, and by subspecies *terminalis* Woods. with truncate or rounded leaf bases, the former more common in southern parts of the state, the latter more common in the northern portions.

A beautiful orange-flowered species of sandy soil, open fields, and roadsides, particularly common in the sandy areas in central Wisconsin. Flowering from mid-June through August. Small dots in Map 3 represent sight records by J. W. Thomson.

4. A. EXALTATA L. Map 4.

A. phytolaccoides Pursh.

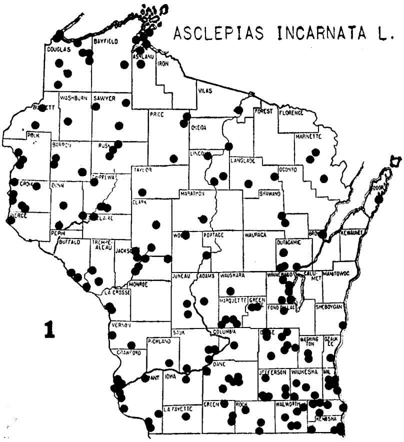
Stem relatively stout, simple, glabrous. Leaves large, thin, long-pointed at both ends. Inflorescences lax. Flowers white, on pedicels as long or longer than the peduncle.

Found in moist or dry woods, roadside thickets and open fields. Flowering from mid-June to mid-July.

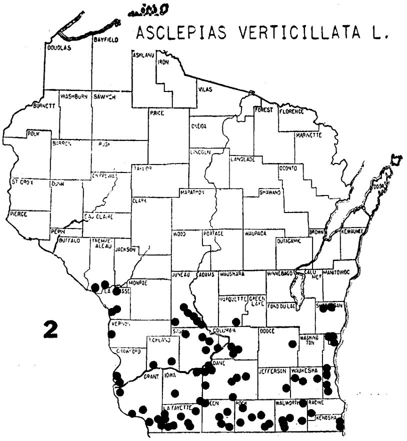
5. A. AMPLEXICAULIS Sm. Map 5.

Distinguished by the thick, glaucous leaves, deeply cordate at base and often crimped on the margin. Flowers dull greenish-purple, in lax inflorescences usually borne on long terminal peduncles (occasional abnormal specimens have almost sessile umbels).

On sandy roadsides, abandoned fields, sandstone ridges, sandy open oak woods, and sandy prairies. Flowering from mid-June to mid-July.


ASCLEPIAS INCARNATA L.

1


ASCLEPIAS VERTICILLATA L.

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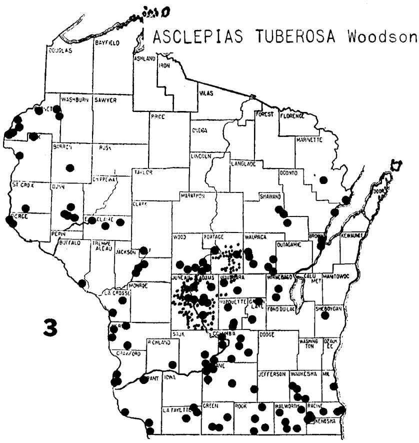
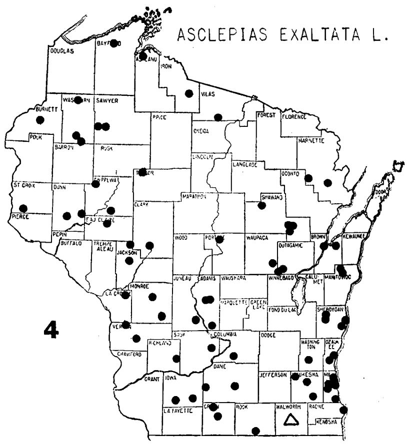
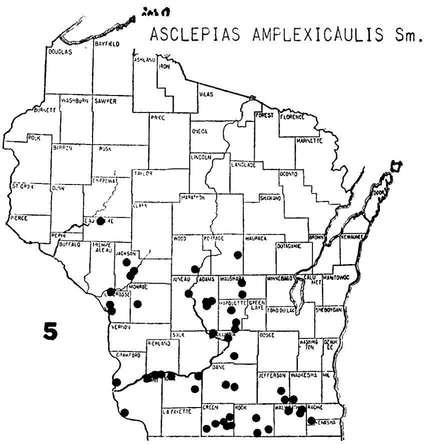

ASCLEPIAS TUBEROSA Woodson

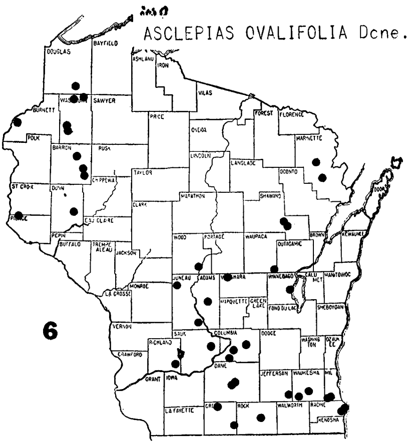
3


ASCLEPIAS EXALTATA L.

4


ASCLEPIAS AMPLEXICAULIS Sm.

5


ASCLEPIAS OVALIFOLIA Dcne.

6

6. A. OVALIFOLIA Dcne. Map 6.

Slender, 2–6 dm. high; leaves in 3–7 pairs, short petioled, oval, ovate or broadly lanceolate, tapering to a blunt or subacute apex, soft-downy beneath. Sometimes resembling *A. purpurascens,* but differing by the yellowish-greenish flowers, and the smaller size of the plant.

Found on prairies, along sandy roadsides, and in sandy woodlands. Flowering from early June to mid-July.

7. A. SYRIACA L. Common Milkweed or Silkweed. Map 7.

Stem coarse, up to 2 m. high, puberulent to pubescent above; leaves lance-oblong to broadly oval. The numerous (50–100), light to dark purple flowers, in each of the several umbels, form globose heads.

A common weed in the southern half of the state, found in prairies, sandy fields, roadside, damp meadows and swamps. Flowering from early June to early August.

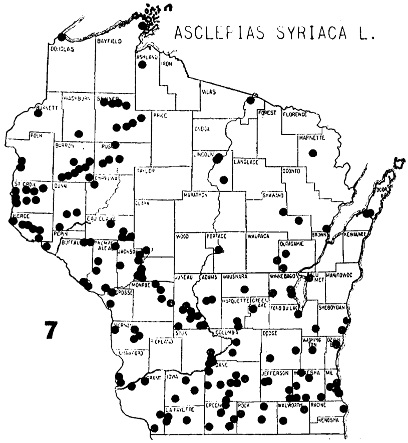
8. A. MEADII Torr. Map 8, cross.

This species is very rare, both in the state and throughout its range in the north-central states. Only two specimens have been collected in Wisconsin, one from near Lancaster, Grant Co., in 1879 (which has been reported on by its collector, E. L. Greene (1898), as coming from "a piece of wild land."). At the University of Wisconsin herbarium a photograph (ex Gray Herbarium) of this specimen shows another Wisconsin collection of *A. meadii* on the same sheet, the latter, however, with insufficient data.

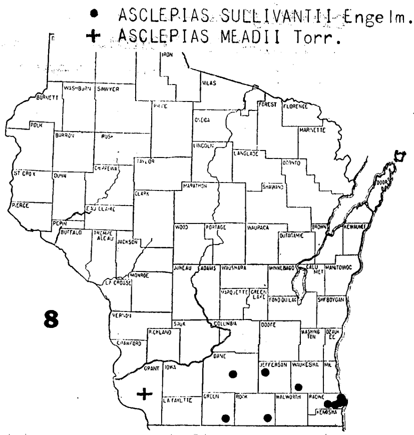
On the basis of its range, Fernald (1925: 317) considered *A. meadii* one of several species that may have survived the Pleistocene glaciations in the "Driftless Area" of Wisconsin and adjoining states. However, only one collection is definitely known from this area, namely the one cited above. In the rest of its range (cf. Woodson 1954: 110, fig. 44) about half of the records come from glaciated territory, while the remainder come from unglaciated territory south of the Glacial border, in Missouri and Kansas. This distribution, as well as the nature of the habitat ("Dry upland prairies and chert-lime glades", (Woodson, loc. cit.)), suggests a southwestern origin, with an evolution and dispersal center perhaps in the ancient Ozarkian uplands, and a subsequent post-glacial northward migration.

9. A. SULLIVANTII Engelm. Map 8, dots.

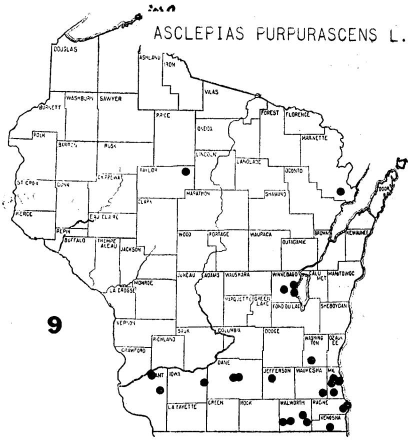
Rather stout, 6–9 dm. tall, glabrous. Leaves on very short petioles not more than 1.5 dm. long, truncate or rounded at base (not cordate), oblong to oblong-elliptic. Similar to *A. syriaca,* but


ASCLEPIAS SYRIACA L.

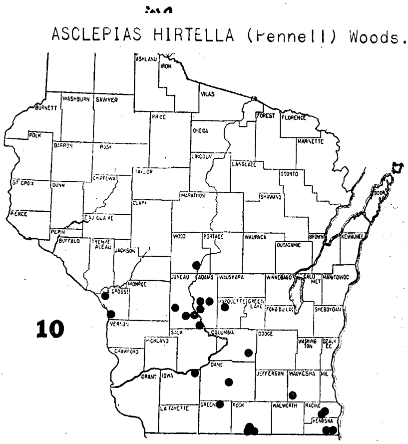
7


● ASCLEPIAS SULLIVANTII Engelm.
+ ASCLEPIAS MEADII Torr.

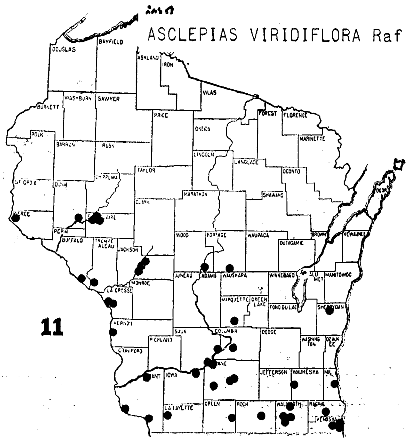
8


ASCLEPIAS PURPURASCENS L.

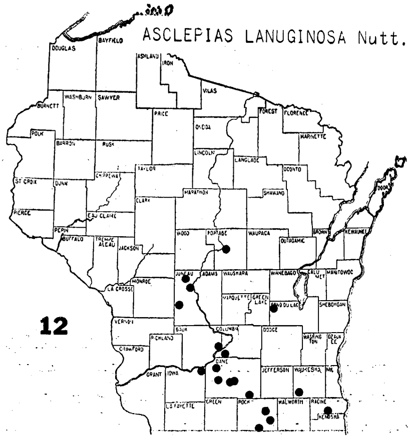
9


ASCLEPIAS HIRTELLA (Pennell) Woods.

10


ASCLEPIAS VIRIDIFLORA Raf

11


ASCLEPIAS LANUGINOSA Nutt.

12

differing by having looser inflorescences and by being glabrous throughout.

A rather rare species of Southern Wisconsin, growing in low prairies and along railroads. Flowering in July.

10. A. PURPURASCENS L. Purple Milkweed. Map 9.

Very similar to *A. syriaca,* but having usually darker purple flowers with petals glabrous outside, and usually somewhat narrower, more acute leaves.

An uncommon prairie species, found along roads in ditches and hedges, and along railroad relic prairies. Flowering from mid-June to mid-July.

SUBGENUS II. ACERATES (Ell.) Woods.

11. A. HIRTELLA (Pennell) Woodson. Map 10.

Acerates hirtella Pennell.

Acerates floridana of American authors, not of Lamarck.

Leaves many and crowded, very narrow, scabrous. Inflorescences often more than 3, occasionally as many as 8.

An uncommon species of roadsides, sandy ground, prairie, and wet meadows, mainly in the central part of the state. Flowering in July and August.

12. A. VIRIDIFLORA Raf. Map 11.

Acerates viridiflora (Raf.) Pursh.

Similar to *A. hirtella,* but with fewer, often broader, leaves and rarely with more than 3 inflorescences.

In sandy and mesic, relic prairies along railroads, "goat prairies" and dry hillsides, sometimes with limestone outcroppings, and pastures. Flowering from early June to late August.

13. A. LANUGINOSA Nutt. Map 12.

Asclepias nuttalliana Torr.

Acerates monocephala Lapham ex Gray.

Acerates lanuginosa (Nutt.) Dcne.

Low, generally pilose, with clustered stems. Inflorescences solitary and terminal, sessile or subsessile.

A rare species in Wisconsin, found in dry, gravelly and sandy prairies, hill-prairies, along railroads, and in sand flats near the Wisconsin River. Flowering from late May to July.

The type of *Acerates monocephala* Lapham ex. A. Gray (Man. Bot. Northern U. S. 1858, p. 704) came from "Prairies of Wisconsin." Authentic material, collected or annotated by Lapham, is in the University of Wisconsin Herbarium.

II. CYNANCHUM

Represented in Wisconsin by one species:

14. C. NIGRUM (L.) Pers.

Stem twining; leaves opposite; juice not milky; flowers axillary, blooming in June. Fruit fusiform lanceolate, smooth, ripe in July. Introduced from Europe. Collected twice at Potosi, Grant County, in 1913 and 1926.

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PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. NO. 41. LABIATAE—MINT FAMILY

ROBERT C. KOEPPEN
Herbarium of the University of Wisconsin

The distribution of the Labiatae of Wisconsin, their habitats and dates of flowering, were compiled from specimens and field notes in the herbaria of the University of Wisconsin (WIS), the Milwaukee Public Museum (MIL), and the University of Minnesota (MINN). Other sources of information are cited in the text. The symbols used on the distribution maps to designate the exact localities where collections were made are given in the text; circles around these symbols indicate a county record without specific locality.[1] Nomenclature and phylogenetic sequence of genera follows that of the *New Britton and Brown Illustrated Flora* (Gleason, 1952), excepting the genera *Physostegia* and *Dracocephalum,* where *Gray's Manual of Botany,* Ed. 8 (Fernald, 1950) was used. In the text, references are given to pertinent monographic studies.

Grateful acknowledgment is due to Gerald B. Ownbey, curator of the herbarium of the University of Minnesota, and Albert M. Fuller, curator of the herbarium of the Milwaukee Public Museum, who were kind enough to provide the use of their herbarium facilities for this study; to John W. Thomson whose constructive criticism of the final draft was exceedingly helpful; and especially to Hugh H. Iltis for his assistance and advice in the preparation of this report as well as for his critical reading of the manuscript.

LABIATAE OF WISCONSIN

Annual or perennial herbs (Wisconsin members) with square stems, usually producing aromatic oils; leaves opposite, estipulate, simple, mostly serrate but in some entire to lobed; inflorescence composed of axillary cymes that form 1 or more apparent whorls (verticils) or the flowers solitary in each axil *(Scutellaria, Physostegia),* the primary axis often with shortened internodes, the verticils then appearing as a continuous spike or head; flowers perfect; calyx persistent, typically 5-lobed, often 2-lipped (bilabiate), with 5–15 conspicuous nerves; corolla sympetalous, 5-lobed, bilabiate (nearly regular in *Mentha* and *Lycopus*); stamens 2 or 4, epipetalous, with the anterior pair usually longer (didynamous);

[1] Many of the specimens on which this report is based were collected on field trips supported by grants from the Wisconsin Alumni Research Foundation.

pistil 1; ovary superior, 4-lobed but 2 carpellate, the single style gynobasic, arising between the 4 lobes, shortly 2-branched; fruit of 4 nutlets, usually separating at maturity.

Key to Genera

a. Calyx with a distinct protuberance on the back of the upper lip; flowers blue .... 4. *Scutellaria*

a. Calyx without any protuberance on the back of the upper lip.

- b. Corolla appearing one-lipped, the upper lip either very short, or its lobes appearing laterally on the margins of the lower lip; corolla large, 10–18 mm. long.
  - c. Flowers in definite terminal racemes, the bracts linear, much reduced; leaves with definite petioles, lanceolate to ovate, serrate; corolla pink, split on the upper side .... 2. *Teucrium*
  - c. Flowers in the axils of large foliage-like bracts; leaves mostly sessile, spatulate; teeth rounded; corolla deep blue, upper lip very short, but not split .... 1. *Ajuga*
- b. Corolla two lipped or regular, large or small.
  - d. Stamens 2.
    - e. Lower lip of corolla fringed; inflorescence a terminal panicle; flowers yellow, lemon scented .... 27. *Collinsonia*
    - e. Lower lip of corolla lobed or entire, not fringed; inflorescences axillary or terminal racemes or heads.
      - f. Calyx regular or nearly so, its lobes essentially all alike.
        - g. Corolla less than 5 mm. long, nearly regular, white; plants not aromatic .... 25. *Lycopus*
        - g. Corolla 15–50 mm. long, strongly bilabiate, lavender, yellow, or crimson, rarely white; plants strongly aromatic.. 16. *Monarda*
      - f. Calyx irregular, bilabiate.
        - h. Flowers axillary, 6 mm. or less long, in loose few-flowered verticils subtended by ordinary foliage leaves; base of calyx gibbous on lower side .... 18. *Hedeoma*
        - h. Flowers terminal, 6–20 mm. long, in racemes or heads, the bracteal leaves much reduced in size; base of calyx not gibbous.
          - i. Verticils with less than 12 flowers; more than 5 verticils in each inflorescence .... 15. *Salvia*
          - i. Verticils with numerous flowers; 1–5 verticils in each inflorescence .... 17. *Blephelia*
  - d. Stamens 4.
    - j. Calyx lobes with stiff, bristle-like, spiny tops.
      - k. Leaves palmately veined and palmately lobed...... 13. *Leonurus*
      - k. Leaves pinnately veined, serrate .... 11. *Galeopsis*
    - j. Calyx lobes neither stiff nor spiny, usually with acuminate but flexible tips.
      - l. Flowers axillary, subtended by ordinary or only slightly reduced foliage leaves; internodes of inflorescence not markedly shorter than those of the stem.
        - m. Leaves entire.
          - n. Calyx regular, the lobes equal; corolla barely exceeding calyx lobes; stems pubescent .... 3. *Isanthus*
          - n. Calyx irregular, the lobes unequal; corolla exceeding calyx lobes by at least 3 mm.; stems glabrous..... 19. *Calamintha*

m. Leaves serrate or crenate.
o. Leaves broadly ovate to reniform, at least one-half times as broad as long.
p. Flowers white or reddish-purple, sessile; upper lip of corolla strongly concave; plants ascending or erect .... 12. *Lamium*
p. Flowers blue, distinctly pedicelled; upper lip of corolla not strongly concave; plants creeping .... 7. *Glecoma*
o. Leaves lanceolate, oblanceolate, or oblong, more than twice as long as broad.
q. Flowers large, about 25 mm. long; calyx and corolla strongly bilabiate .... 8. *Dracocephalum*
q. Flowers small, 7 mm. or less long; calyx and corolla nearly regular .... 26. *Mentha*
l. Flowers in terminal spikes, racemes, or heads; if verticils subtended by foliose bracts, then the bracts reduced in size; internodes of inflorescence shortened.
r. Leaves entire.
s. Principal leaves 10–40 mm. wide, the petioles 10 mm. or more long; flowers usually blue-violet .... 9. *Prunella*
s. Principal leaves 10 mm. or less wide, sessile (long attenuate to the base in No. 20) or with petioles less than 5 mm. long.
t. Flowers whitish, in many small, dense, globose heads at the tips of branchlets, normally none at lower nodes .... 24. *Pycnanthemum*
t. Flowers blue or purple, in dense or loose racemes, the inflorescence at least somewhat elongate.
u. Leaves 5–10 mm. long, usually elliptic; calyx 3–4 mm. long; corolla purple .... 23. *Thymus*
u. Leaves 10–30 mm. long, linear, lanceolate, or oblanceolate; calyx 6–8 mm. long; corolla bluish or white.
v. Corolla dark blue, about 10 mm. long; plants perennial from a woody rhizome .... 22. *Hyssopus*
v. Corolla pale pink-purple to white, 5–7 mm. long; plants annual .... 20. *Satureja*
r. Leaves serrate or crenate.
w. Stamens ascending along the upper lip of the corolla, or straight; none of the calyx lobes banner-like, nor with decurrent edges.
x. Flowers singly in the axil of each bracteal leaf, 15–30 mm. long, with 2 flowers at a node .... 10. *Physostegia*
x. Flowers 2—many in the axil of each bracteal leaf, less than 15 mm. long, with at least 4 flowers at a node.
y. Inflorescences secund, very dense, terminal mostly on the lateral branches .... 28. *Elsholtzia*
y. Inflorescences terete.
z. Flowers small, the calyx less than 4 mm. long; corolla nearly regular, its lobes about equal; plants strongly aromatic .... 26. *Mentha*
z. Flowers larger, the calyx 4 mm. or more long; corolla bilabiate, its lobes unequal; plants aromatic or odorless.
aa. Bracts of verticils all setaceous, about 10 mm. long, hirsute; flowers in a dense, subglobose, terminal, head-like glomerule, or in vigorous plants, with 2 glomerules in the upper most axils 21. *Clinopodium*

aa. Bracts of verticils ovate or lanceolate, if setaceous, neither long nor hirsute; flowers not in head-like glomerules.

bb. Inflorescence a long, few-flowered spike; flowers all sessile, 6–8 at a node; internodes clearly visible .... 14. *Stachys.*

bb. Inflorescence many-flowered, more or less compact; flowers both pedicellate and pedunculate; internodes rarely visible (except in No. 6).

cc. Stamens long-exserted from the corolla; plants large, often more than 70 cm. tall..5. *Agastache.*

cc. Stamens included or only barely exserted from corolla; plants usually less than 70 cm. tall.

dd. Flowers whitish; plants canescent throughout, strongly aromatic; leaves crenate-dentate, the teeth obtuse; calyx nearly regular..6. *Nepeta.*

dd. Flowers bluish; plants glabrous to sparingly pubescent, not strongly aromatic; calyx strongly bilabiate.

ee. Leaves obscurely toothed or some of them entire; bracts broadly ovate, ciliate .... 9. *Prunella.*

ee. Leaves sharply serrate; bracts lanceolate, toothed, the teeth ending in short awns.... .... 8. *Dracocephalum.*

w. Stamens deflexed along the lower lip of the corolla; upper lip of calyx banner-like, its edges decurrent along the calyx tube .... 29. *Ocimum.*

1. AJUGA L. BUGLE

1. A. GENEVENSIS L. Erect Bugle. Map 1.

Introduced from Europe and occasionally escaping from gardens. Apparently established in Waukesha County. Flowering mid-May thru June.

Ajuga repens L. has been reported for Wisconsin by Fernald (1950), but none of the Wisconsin collections examined for this study had stolons, triangular-ovate calyx lobes, or approached the glabrescence of that species.

2. TEUCRIUM L. GERMANDER; WOOD SAGE

[McClintock and Epling. A Revision of Teucrium in the New World. Brittonia 5:491–510. 1946.]

1. T. CANADENSE L.

Gleason (1952) recognizes three varieties of *T. canadense*. The two varieties occurring in Wisconsin are not clearly defined. However, most plants can be assigned to one variety or the other on the basis of calyx and stem pubescence.

a. Calyx and stem pubescence of short (0.5 mm. or less), curly, felt-like, typically eglandular, hairs .... 1a. *T. canadense* var. *virginicum.*
a. Calyx and stem pubescence with at least some longer (1.0 mm.), spreading or only archingly recurved, typically glandular, hairs .... 1b. *T. canadense* var. *occidentale.*

1a. T. CANADENSE L. var. VIRGINICUM (L.) Eaton. Map 2, dots.

Distributed mostly in the southern portion of the state, extending northward to Polk, Lincoln, and Marinette Counties. Common in rich low woods, on creek banks, lake shores, and moist places; occasionally on drier sites, as sandy roadsides, limestone outcrops, prairies, and dry woods. Flowering early June thru August.

1b. T. CANADENSE L. var. OCCIDENTALE (Gray) McClintock & Epling. Map 2, crosses.

T. occidentale Gray.

Mostly in the southern portion of the state, extending northward to Burnett, Forest, and Door Counties. Habitat and flowering times as in No. 1a.

3. ISANTHUS MICHX. FALSE PENNYROYAL

1. I. BRACHIATUS (L.) BSP. Map 3.

I. brachiatus (L.) BSP. var. *linearis* Fassett, Rhodora 35:388, 1933.

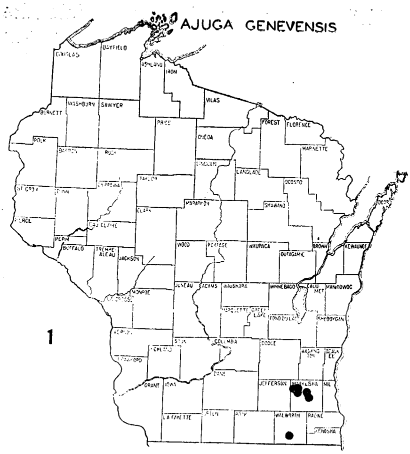
Locally common in southern Wisconsin on quartzite, limestone, or granite outcrops, and sandy or gravelly slopes, pastures, and stream banks. Flowering end of July thru mid-September.

Fassett described var. *linearis* as a northern variety of the species. Examinations of herbarium specimens reveal that small, narrow-leaved plants are not uncommon in the Eastern United States, and that within a single population (e.g. W. Rutland, Vermont, *W. W. Eglleston s. n.* (WIS); "Pinnacle Point", Barry County, Missouri, *Moore & Iltis 533* (WIS)) both robust plants with wide, 3-nerved leaves as well as depauperate plants with narrow, 1-nerved leaves may be found. This form, therefore, does not seem to deserve formal taxonomic recognition.

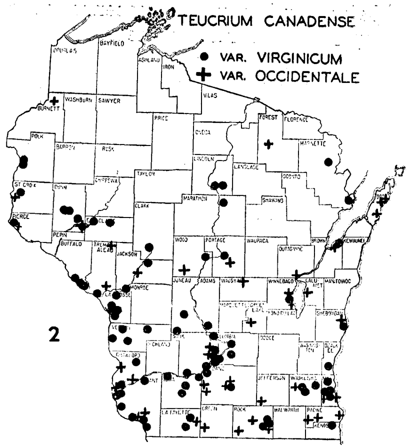
4. SCUTELLARIA L. SKULLCAP

[Epling. American Species of Scutellaria. Univ. Calif. Publ. Bot. 20:1–146. 1942.]

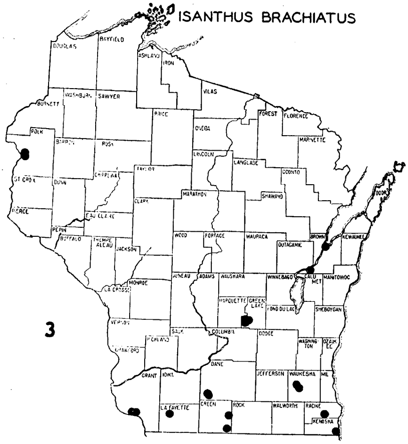
a. Plants with moniliform rhizomes; leaves 2 cm. long or less, entire or subentire; plants 10–20 cm. tall.
b. Plant obviously pubescent; usually some of the leaves sparingly toothed. Under the lens: upper stems and leaves with copious spreading hairs and longer capitate glands .... 1. *S. parvula.*


AJUGA GENEVENSIS

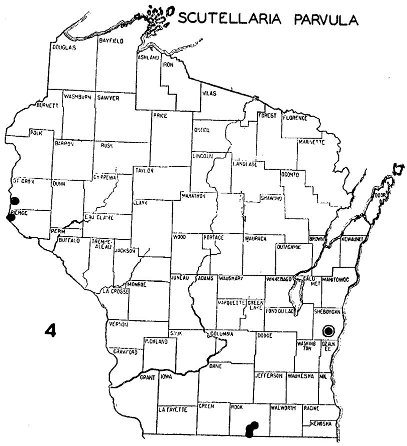
1


TEUCRIUM CANADENSE
● VAR. VIRGINICUM
+ VAR. OCCIDENTALE

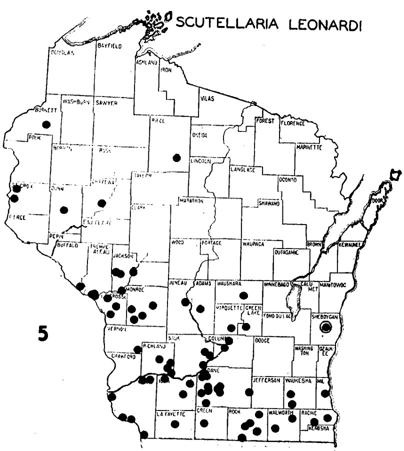
2


ISANTHUS BRACHIATUS

3


SCUTELLARIA PARVULA

4


SCUTELLARIA LEONARDI

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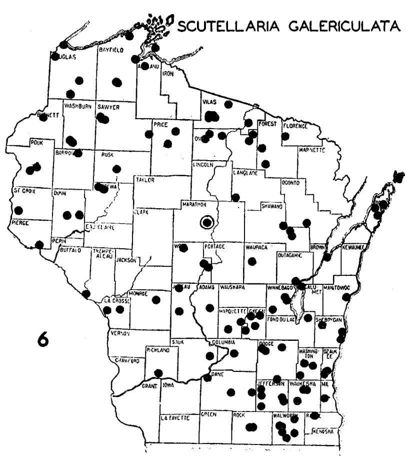

SCUTELLARIA GALERICULATA

6

b. Plants subglabrous; leaves usually entire, often revolute. Under the lens: upper stem (at least on angles) and leaves with short ascending hairs, eglandular .... 2. *S. leonardi.*

a. Plants with filiform rhizomes, stolons, or slender tap roots; larger leaves more than 2 cm. long, toothed; plants commonly 30 cm. tall or more.

c. Petioles short, 1–3 mm. long; leaves mostly broadly lanceolate to oblong, crenulate .... 3. *S. galericulata.*

c. Petioles 10 mm. long or longer; leaves deltoid-ovate to ovate-cordate, crenate to serrate.

d. Largest flowers 10–23 mm. long; racemes terminal or subterminal; leaves broadly ovate-cordate, 6–12 cm. long, 3.5–9.2 cm. broad, crenate-serrate; stem from a narrow taproot-like base; plants softly pilose throughout .... 4. *S. ovata* subsp. *versicolor.*

d. Largest flowers 6–9 mm. long; racemes usually axillary, secund; leaves deltoid-ovate, 3–7 cm. long, 2.0–3.5 cm. broad, coarsely serrate; stems from filiform rhizomes; plants with ascending hairs, at least on the stem angles .... 5. *S. lateriflora.*

1. S. PARVULA Michx. Small Skullcap. Map 4.

Prairies, limestone ledges, creek-sides, and railroad embankments; not common in Wisconsin. Flowering in June. Very similar to the next but with broader, more ovate leaves, and greater pubescence.

2. S. LEONARDI Epl. Smooth Small Skullcap. Map 5.

S. parvula Michx. var. *Leonardi* (Epling) Fern.

Common in the southern half of the state on rocky bluffs and outcrops of granite, limestone, and sandstone; in sandy places of fields, pastures, steep prairies, and river bottoms, oak-openings and jack pine woods; occurring northward to Burnett, Price, and Sheboygan Counties. Flowering end of May thru July.

3. S. GALERICULATA L. Common Skullcap. Map 6.

S. epilobilifolia A. Hamilton.

Common throughout the state in swales, bogs, low meadows, river bottoms, lakeshores, and other wet places. Flowering end of May thru August.

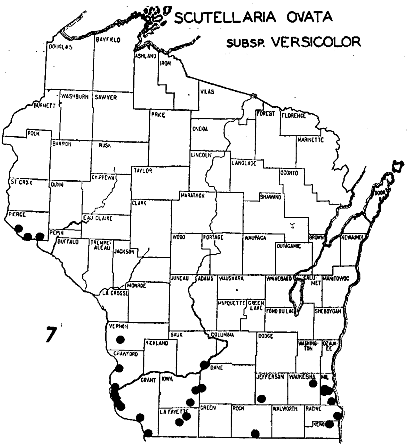
4. S. OVATA Hill subsp. VERSICOLOR (Nutt.) Epling. Heart-leaved Skullcap. Map 7.

S. ovata Hill var. *versicolor* (Nutt.) Fern.

Local on oak ridges, wooded slopes, and bluffs of southern Wisconsin; northward to Pierce and Milwaukee Counties. Flowering from the end of June to the end of August.

5. S. LATERIFLORA L. Mad-Dog Skullcap. Map 8.

Common throughout the state on lakeshores, river banks, tamarack bogs, marshes, low woods, and in roadside ditches. Flowering mid-July to mid-September.


SCUTELLARIA OVATA
SUBSP. VERSICOLOR
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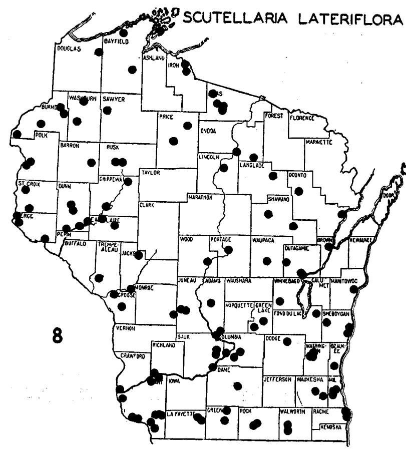
SCUTELLARIA LATERIFLORA
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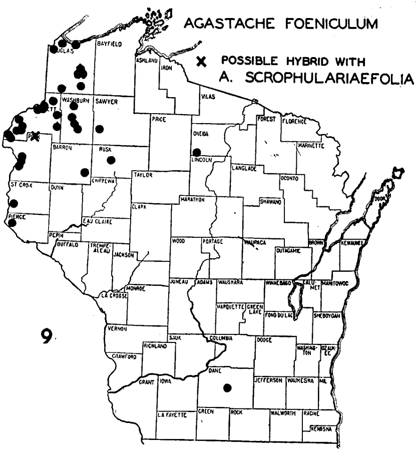
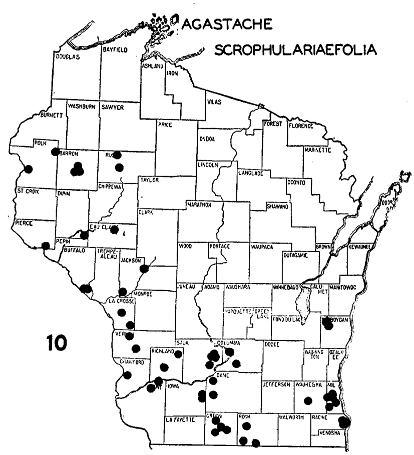

AGASTACHE FOENICULUM
× POSSIBLE HYBRID WITH
A. SCROPHULARIAEFOLIA
9


AGASTACHE
SCROPHULARIAEFOLIA
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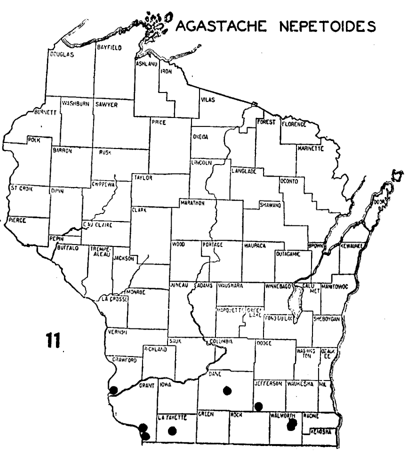
AGASTACHE NEPETOIDES
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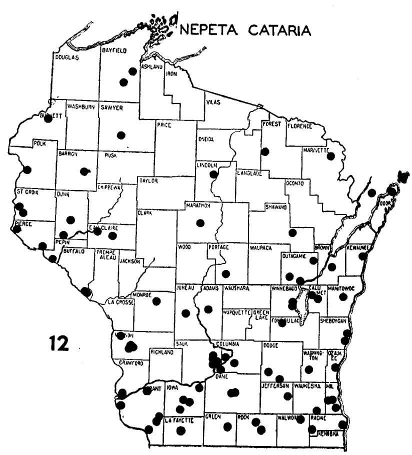

NEPETA CATARIA
12

5. AGASTACHE CLAYTON. GIANT-HYSSOP

[Lint and Epling. A Revision of Agastache. Am. Midl. Nat. 33:207–230. 1945.]

a. Under surface of leaves whitened with very short, dense, felt-like hairs; upper surface glabrous; bracts pubescent, often violet tinged; calyx pubescent, the teeth violet tipped; corolla blue .... 1. *A. foeniculum.*

a. Under surface glabrous, or more often with spreading hairs, tomentose to pilose; upper surface glabrous to pilose; bracts glabrous or minutely pubescent, green or pinkish; calyx glabrate, the teeth green or reddish; corolla rose, purple or yellow.

b. Calyx teeth triangular-lanceolate, acute to acuminate, about 2 mm. long, often pinkish; bracts mostly abruptly acuminate to caudate, typically pink colored at margins, glabrous or glabrescent; corolla rose or purple; stem often reddish .... 2. *A. scrophulariaefolia.*

b. Calyx teeth ovate, acute to obtuse, about 1 mm. long, green; bracts acute to acuminate, green, usually pubescent, with ciliolate margins; corolla yellow; stem green .... 3. *A. nepetoides.*

1. A. FOENICULUM (Pursh) Kuntze. Blue or Fragrant Giant-Hyssop. Map 9.

Sandy fields, prairies, pine barrens, and waste places of the northwestern counties. The Oneida and Dane County collections, which come from outside the main range of the species, were made on railroad embankments. Flowering mid-July to mid-October.

According to Lint and Epling (1945) this species reaches its eastern limit in Wisconsin. A collection cited by them (*J. J. Davis s.n.* Lewis, Wis., Aug. 1, 1924. (WIS, MIL)) has calyces, leaves, and pubescence intermediate between those of *A. foeniculum* and *A. scrophulariaefolia* and may be of hybrid origin ("X" on Map 9.).

2. A. SCROPHULARIAEFOLIA (Willd.) Kuntze. Purple or Figwort Giant-Hyssop. Map 10.

Open woods southwest of the Northwest to Southeast climatic "tension" zone. Flowering mid-July thru September.

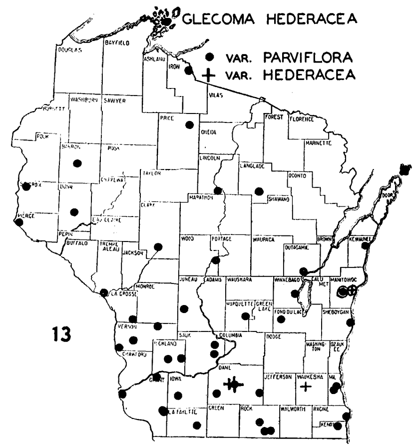
3. A. NEPETOIDES (L.) Kuntze. Yellow or Catnip Giant-Hyssop. Map 11.

Open wooded areas. Not common in Wisconsin. Flowering end of July to mid-September.

6. NEPETA L. CATNIP

1. N. CATARIA L. Map 12.

Native of Europe, introduced into herb gardens, and now thoroughly naturalized and widespread in weedy pastures, yards, fence rows, roadsides, railroad embankments, open woods, and stream banks throughout the state. Flowering early June to early October.



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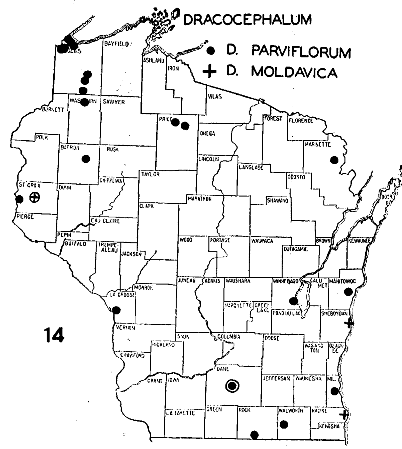

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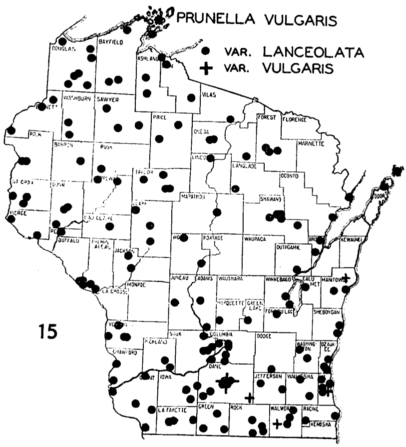

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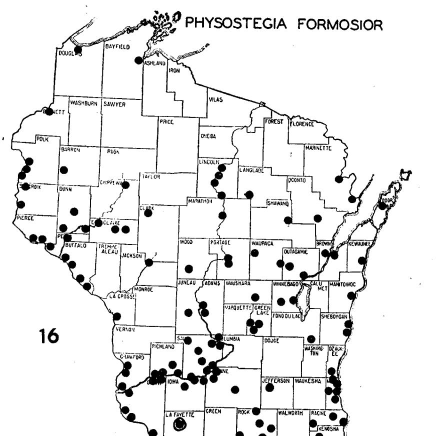

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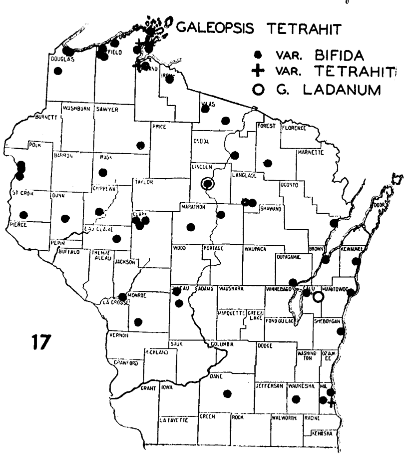

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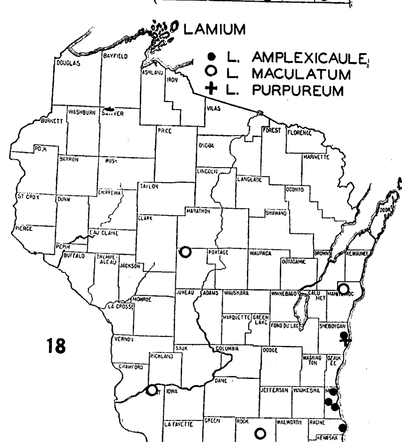

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7. GLECOMA L. GROUND IVY; GILL-OVER-THE GROUND; CREEPING-CHARLIE

1. G. HEDERACEA L. Two varieties are found in Wisconsin.
Nepeta hederacea BSP.
Nepeta Glechoma Benth.

a. Corolla 15–23 mm. long; leaves green.... 1a. *G. hederacea* var. *hederacea.*
a. Corolla 9–15 mm. long; leaves often reddish .... 1b. *G. hederacea* var. *parviflora.*

1a. G. HEDERACEA L. var. HEDERACEA. Map 13, crosses.
Naturalized from Europe. Not widespread in Wisconsin. Flowering early May thru June.

1b. G. HEDERACEA L. var. PARVIFLORA (Benth.) Druce. Map 13, dots.
G. hederacea L. var. *micrantha* Moricand.
Nepeta hederacea BSP. var. *parviflora* Druce.
Naturalized from Europe, common and widespread in Wisconsin around habitations. Flowering early May thru June.

This species forms extensive patches on moist shady soil under trees and around buildings, often becoming a nuisance.

8. DRACOCEPHALUM L. DRAGONHEAD

a. Inflorescence compact and dense; flowers subtended by bracts; corolla scarcely exceeding the calyx .... 1. *D. parviflorum.*
a. Inflorescence elongate and open; flowers subtended by ordinary foliage leaves; corolla much exceeding the calyx .... 2. *D. moldavica.*

1. D. PARVIFLORUM Nutt. American Dragonhead. Map 14, dots.
Moldavica parviflora (Nutt.) Britt.
In open habitats, not common, throughout Wisconsin. Flowering mid-June thru July.

2. D. MOLDAVICA L. Moldavian Dragonhead or Balm. Map 14, crosses.
Moldavica punctata Moench.
Introduced from central Europe. Flowering June to October (Fernald, 1950).

Of the four Wisconsin collections (WIS), the most recent is a 1914 collection from Sheboygan marked "Hort."; the two collections from St. Croix County were made in 1861, the Racine County one in 1859. No further information is given on the latter three sheets. Quite possibly all these specimens came from herb gardens.

9. PRUNELLA L. SELF-HEAL; HEAL-ALL

1. P. VULGARIS L. Two varieties are recognized in Wisconsin.

a. Stems decumbent or creeping, 10–30 cm. long; leaves ovate .... 1a. *P. vulgaris* var. *vulgaris*.
a. Stems erect or strongly ascending, 30–60 cm. long; leaves lanceolate .... 1b. *P. vulgaris* var. *lanceolata*.

1a. P. VULGARIS L. var. VULGARIS. Map 15, crosses.

Introduced from Europe, rare in Wisconsin, found mostly in lawns. Flowering end of June thru September.

1b. P. VULGARIS L. var. LANCEOLATA (Bart.) Fern. Map 15, dots.

Common throughout the state on sandy prairies, fields, yards, pastures, and roadsides, and in woodlands of all kinds. Flowering end of June thru September.

10. PHYSOSTEGIA BENTH. FALSE DRAGONHEAD; OBEDIENT PLANT

1. P. FORMOSIOR Lunell. Map 16.
   Dracocephalum formosius (Lunell) Rydb.
   P. speciosa var. *glabriflora* Fassett.

Locally abundant in low lands throughout the state; as lake, river, and stream banks, sedge meadows, marshes, swales, and flood-plain forests. Flowering from the end of July to early October.

The Wisconsin specimens have been variously grouped as to species, but following McClintock's 1947 unpublished study of this genus, as revealed by her annotations in the University of Wisconsin Herbarium (as *Dracocephalum formosius*), there is only one taxon in the state.

A very showy species, frequently cultivated in flower gardens. The name obedient plant is derived from the tendency of the corolla to remain in whatever position it is placed.

11. GALEOPSIS L. HEMP-NETTLE

a. Stem hispid, the nodes swollen; leaves ovate, coarsely serrate .... 1. *G. tetrahit*.
a. Stem finely recurved pubescent, the nodes not swollen; leaves linear to lanceolate, shallowly serrate to entire .... 2. *G. ladanum*.

1. G. TETRAHIT L.

Two varieties are found in Wisconsin.

a. Leaf bases rounded; corolla about 22 mm. long, the lower lobe truncate .... 1a. *G. tetrahit* var. *tetrahit*.
a. Leaf bases cuneate; corolla about 15 mm. long, the lower lobe emarginate .... 1b. *G. tetrahit* var. *bifida*.

1a. G. TETRAHIT L. var. TETRAHIT. Map 17, crosses.

Collected near rivers and lakes, not common. Flowering mid-July to September.

1b. G. TETRAHIT L. var. BIFIDA (Boenn.) LeJ. and Court. Map 17, dots.

In low waste places and pastures, occasionally in woods; the more abundant variety in Wisconsin. Flowering early July thru September.

2. G. LADANUM L. var. ANGUSTIFOLIA Wallr. Red Hemp-Nettle. Map 17, circle.

Our one collection is from Calumet County: considerable colonies within a mile south of Potter, Aug. 26, 1922, *H. C. Benke 3602* (MIL).

12. LAMIUM L. DEAD-NETTLE

a. Upper leaves sessile and clasping, lower leaves long petioled; corolla 12–18 mm. long, the upper lip 3–5 mm. long .... 1. *L. amplexicaule.*
a. All leaves petioled.
  b. Corolla 8–15 mm. long, the upper lip 3–5 mm. long; leaves deep green or purplish, upper ones densely crowded .... 2. *L. purpureum.*
  b. Corolla 20–25 mm. long, the upper lip 7–11 mm. long; leaves often with a pale blotch along the midrib, none of them crowded.... 3. *L. maculatum.*

1. L. AMPLEXICAULE L. Henbit. Map 18, dots.

Roadsides, railroad embankments, and waste places of Sheboygan, Milwaukee, and Racine Counties. A common weed in the southern states, but not persistent in Wisconsin. Flowering March to November (Gleason, 1952), in Wisconsin probably June to September.

2. L. PURPUREUM L. Purple Dead-Nettle. Map 18, cross.

A single waif collected in the city of Sheboygan, June 1878, by *J. J. Brown s. n.* (WIS).

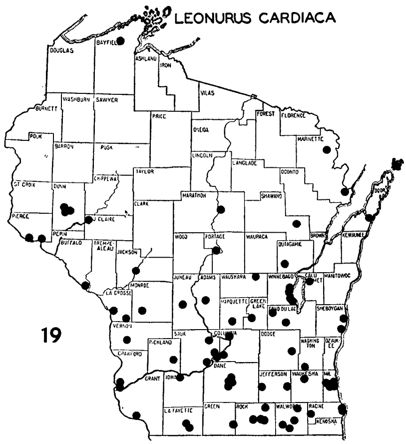
3. L. MACULATUM L. Variegated Dead Nettle. Map 18, circles.

Native of Eurasia, occasionally escaping from cultivation. Collected to date only from Grant, Wood, Manitowoc, and Rock Counties. Wisconsin collections flowering July thru August.

13. LEONURUS L. MOTHERWORT

1. L. CARDIACA L. Map 19.

Open woods, pastures, river bottoms, and waste places. Native of central Asia, introduced in herb gardens and freely escaping throughout Wisconsin, but more common in the southern half of the state. Flowering end of May thru September.



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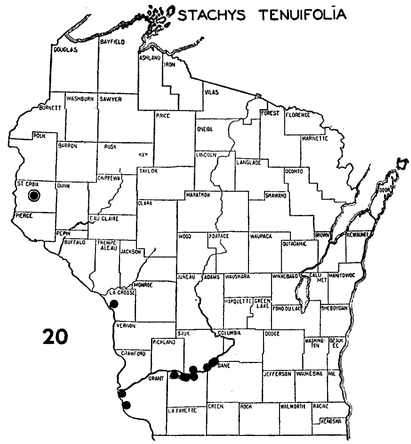

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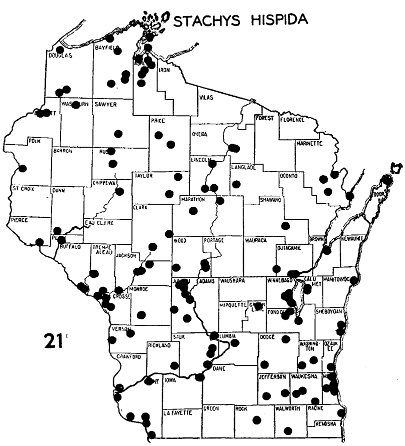

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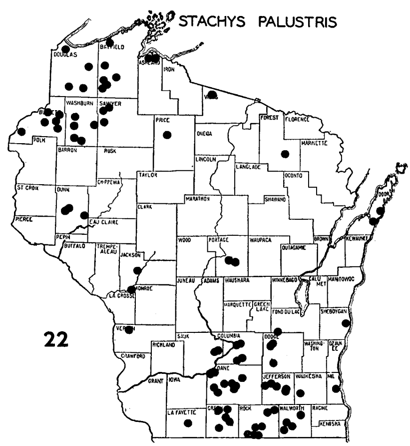

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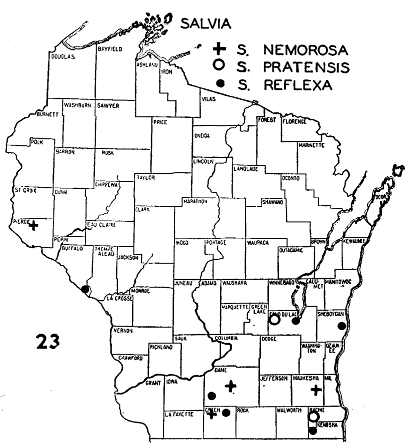

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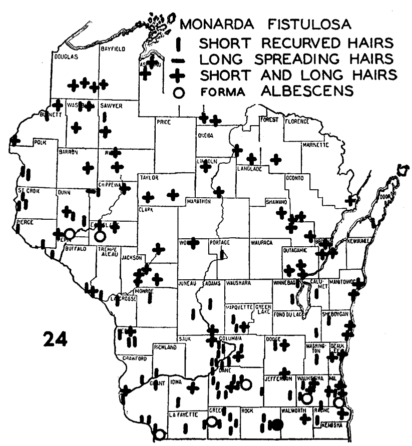

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14. STACHYS L. HEDGE-NETTLE

[Epling. Preliminary Revision of American Stachys. Fedde Repert. Spec. Nov. Beih. 80:79–81. 1934.]

The pubescence characters of the species of this genus, in Wisconsin, exhibit a tendency to intergrade, especially on the upper stem. Some specimens of the glabrous *S. tenuifolia* have hispid hairs on the upper stem angles, as in *S. hispida*. Individuals of *S. hispida* may be found with hairs on the sides as well as the angles of the upper stem, as in *S. palustris*. Following the available literature, three species are found within the state.

a. Plants glabrous, occasionally subglabrous above; leaf petioles 8–25 mm. long .... 1. *S. tenuifolia*.

a. Plants pubescent, at least on the stem angles; leaves sessile or with petioles up to 10 mm. long.

b. Stems hispid on the angles only; leaves with petioles up to 10 mm. long .... 2. *S. hispida*.

b. Stems pubescent on the sides, as well as the angles; leaves sessile or subsessile .... 3. *S. palustris*.

1. S. TENUIFOLIA Willd. Map 20.

Occasionally on the Wisconsin River bottoms, or in moist weedy pastures, mostly in the southwestern portion of the state. Flowering end of July to early September.

2. S. HISPIDA Pursh. Map 21.

Common throughout the state on lake shores, river and stream banks, in marshes, bogs, low fields, and moist woods. Flowering end of June to mid-September.

3. S. PALUSTRIS L. Map 22.

Common throughout Wisconsin in moist places, as marshes, bogs, river bottoms, lake shores, ditches, and low pastures. Flowering from the end of June thru the end of September.

Fernald (1950) recognizes nine varieties of this species, Gleason (1952) narrows them to three. It is exceedingly difficult to fit many of the Wisconsin specimens into any of these groupings. Epling (1934, p. 63) states that Wisconsin and Minnesota are the meeting grounds for eastern and western forms and reports numerous intermediates. In view of this observation, and the limited scope of this report, it seems best to treat the Wisconsin plants as part of a *S. palustris* complex and not try to force them into varietal "pigeon-holes".

15. SALVIA L. SAGE

a. Principal leaves 4–12 mm. wide, linear to lanceolate, entire or subentire .... 1. *S. reflexa.*

a. Principal leaves 20–60 mm. wide, ovate-lanceolate to ovate oblong, crenate.

b. Leaves mostly basal, long petioled; corolla 15–20 mm. long .... 2. *S. pratensis.*

b. Leaves cauline, short petioled to sessile; corolla 9–12 mm. long .... 3. *S. nemorosa.*

1. S. REFLEXA Hornem. Map 23, dots.

Very local on limestone outcrops or dry fields and prairies in the southern part of the state, northward to Buffalo, Fond du Lac, and Sheboygan Counties. Flowering early July to mid-October.

2. S. PRATENSIS L. Meadow Sage. Map 23, circles.

Native of Europe, reportedly thoroughly established along the T. M. E. R. & L. right-of-way and the adjacent pasture south of State Highway 20, Rochester, Racine County; not persistent northward. Flowering June to August (Gleason, 1952).

3. S. NEMOROSA L. Map 23, crosses.

S. sylvestris L.

Native of Europe, occasionally escaping into fields, pastures and along railroad tracks, where it is reported as locally abundant. Flowering May to July.

16. MONARDA L. HORSE MINT; WILD BERGAMOT

[McClintock & Epling. A Review of the Genus Monarda. Univ. Calif. Publ. Bot. 20:147–194. 1942.]

a. Stamens and style clearly exserted beyond the upper lip of the corolla; heads terminal, solitary (occasionally two); corolla lilac, white or scarlet.

b. Corolla lavender (rarely white), 15–27 mm. long, the upper lip densely pubescent, bearded at the tip .... 1. *M. fistulosa.*

b. Corolla bright scarlet, 30–50 mm. long, glabrous or sparingly pubescent, not bearded .... 2. *M. didyma.*

a. Stamens and style largely contained within the upper lip of the corolla; heads two or more, forming an interrupted spike; corolla yellowish with purple spots .... 3. *M. punctata* subsp. *villicaulis.*

1. M. FISTULOSA L. Wild Bergamot. Map 24.

M. fistulosa L. var. *mollis* (L.) Benth.

Common throughout the state, on dry prairies, pastures, roadsides, railroad embankments, oak-openings, and pine barrens. Flowering end of June to early September.

The pubescence is variable and three types may be recognized: plants with only short recurved hairs, plants with only long spreading hairs, and intermediates having both kinds. Some taxonomists have given varietal rank to each of these pubescence types, but McClintock & Epling (1942) do not recognize them as varieties.

In Wisconsin, the form with only long spreading hairs is rare. Plants with only short recurved hairs are found more commonly in the southern counties, while those with mixed pubescence are more common northward. White flowered plants (forma *albescens* Farw.) occur sporadically.

2. M. DIDYMA L. Oswego Tea; Bee Balm. Map 25, crosses.

Native of New York, Pennsylvania, and southward on the Appalachian Mountains to Tennessee (McClintock & Epling, 1942: 160, Fig. 4); introduced in flower gardens in Wisconsin and occasionally escaping on moist roadsides. Flowering July to September (Gleason, 1952).

3. M. PUNCTATA L. subsp. VILLICAULIS Penn. Horsemint. Map 25, dots.

A plant of open, dry, sandy soil, especially common on prairies, oak openings, jack pine stands, sandstone outcrops, roadsides, sandy beaches, and abandoned fields, mostly in the southern half of Wisconsin. Flowering end of June to mid-September.

17. BLEPHILIA RAF.

a. Internodes with long spreading hairs; leaves ovate, sharply serrate, with petioles 1–2 cm. long; bracts linear-subulate to lanceolate, green, shorter than the calyx; lower calyx lobes not reaching the sinuses of the upper lip .... 1. *B. hirsuta.*

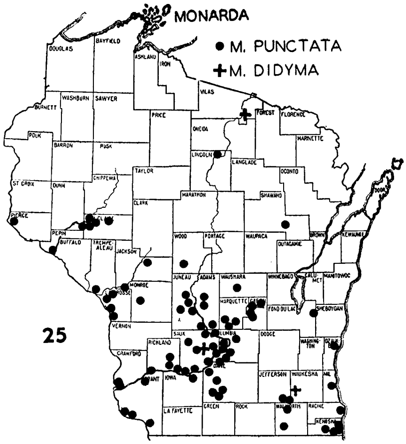
a. Internodes with short recurved hairs; leaves lanceolate to ovate, entire or minutely serrulate, the upper ones of flowering stems sessile or subsessile; outer bracts ovate, acuminate to caudate, often purplish, as long as the calyx; lower calyx lobes extending beyond the sinuses of the upper lip .... 2. *B. ciliata.*

1. B. HIRSUTA (Pursh) Benth. Wood-Mint. Map 26.

Rich woods throughout the state, but nowhere abundant. Flowering early-July to early-September.

2. B. CILIATA (L.) Benth. Map 27.

Low places in open woods, prairies, and meadows. Confined largely to the southeastern portion of the state. Flowering end of May thru mid-August.



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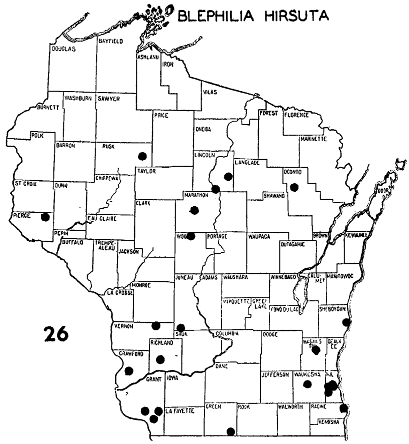

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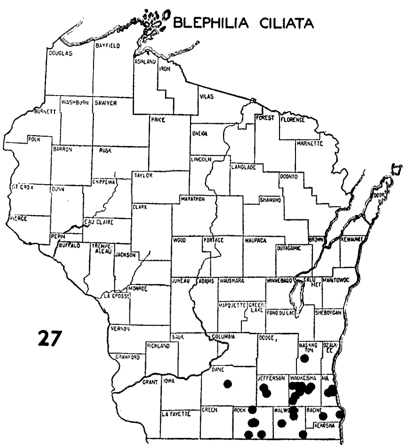

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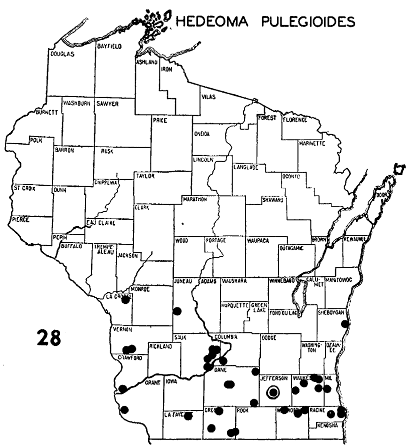

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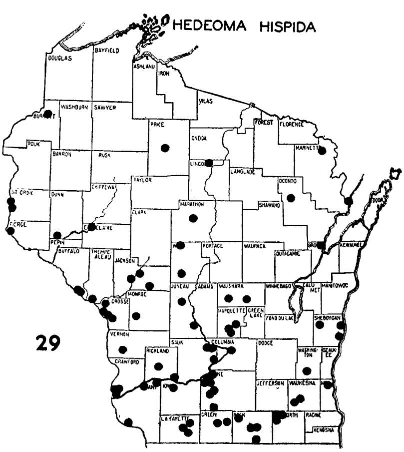

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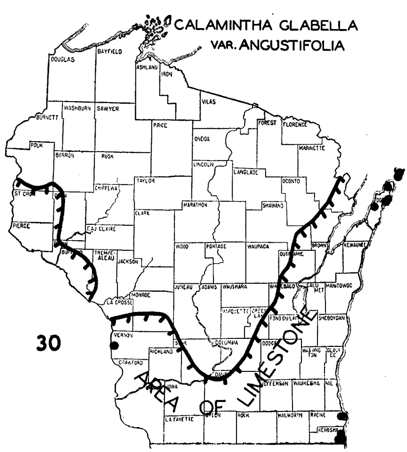

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18. HEDEOMA Pers.

[Epling & Stewart. A Revision of Hedeoma. Fedde Repert. Spec. Nov. Beih. 115:1–49. 1939.]

a. Leaves lanceolate, the principal ones distinctly petiolate, and usually serrate; upper calyx teeth without cilia .... 1. *H. pulegioides.*
a. Leaves linear, sessile, entire; all calyx teeth ciliate .... 2. *H. hispida.*

1. H. pulegioides (L.) Pers. American Pennyroyal. Map 28.

Locally common in sandy soil of pastures, open woods, and roadsides: La Crosse County to Sheboygan County and southward. Flowering mid-July thru August.

2. H. hispida Pursh. Rough Pennyroyal. Map 29.

Dry sandy or gravelly soil of prairies, pastures, roadsides, and waste places throughout the state, especially common southward. Flowering mid-May to early August.

19. CALAMINTHA Moench. Calamint

[DeWolf. Notes on Cultivated Labiates. Baileya 33:148–150. 1954.]

1. C. glabella (Michx.) Benth. var. angustifolia (Torr.) DeWolf. Slender Calamint or Bed's-foot. Map 30.

Satureja glabella (Michx.) Briq. var. *angustifolia* (Torr.) Svenson.

Satureja arkansana (Nutt.) Briq.

Open limestone outcrops along beaches and ravines, or in calcareous meadows. Locally abundant in Door, Racine, and Kenosha Counties on Niagara Dolomite. The isolated Vernon County collection, beyond the general range of the species, is likewise within an area of limestones. Flowering end of July to early October.

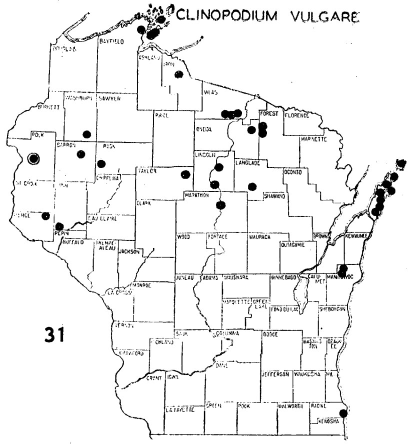
20. SATUREJA L. Savory

[DeWolf. Notes on Cultivated Labiates. Baileya 33:143–150. 1954.]

1. S. hortensis L. Summer Savory. No map.

Native of Europe; introduced in herb gardens and occasionally escaping on roadsides. Two collections from Wisconsin: Sheboygan County, Town of Rhine, August 1903, *Chas. Goessl s. n.* (WIS); Ozaukee County, Port Washington, August 9, 1887, *F. Runge 772* (MIL). Flowering July to September (Gleason, 1952).

For *Satureja glabella* and *S. arkansana* see *Calamintha;* for *S. vulgaris* see *Clinopodium.*



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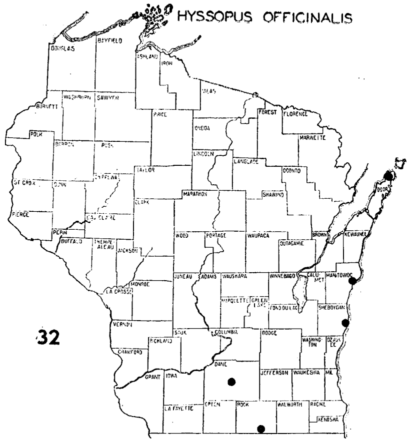

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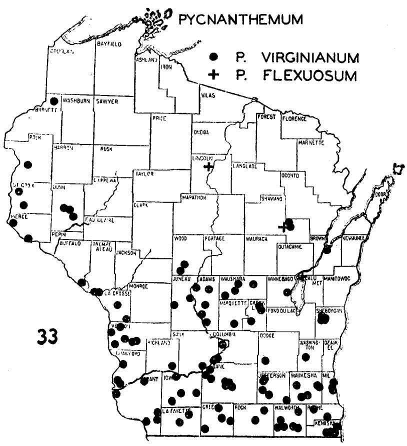

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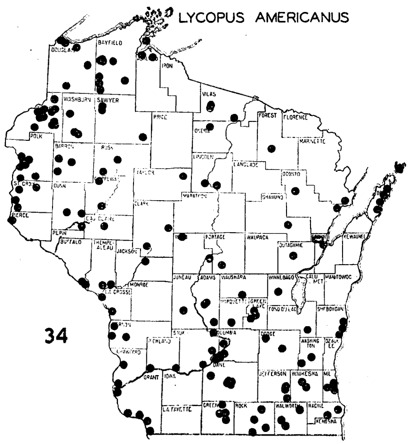

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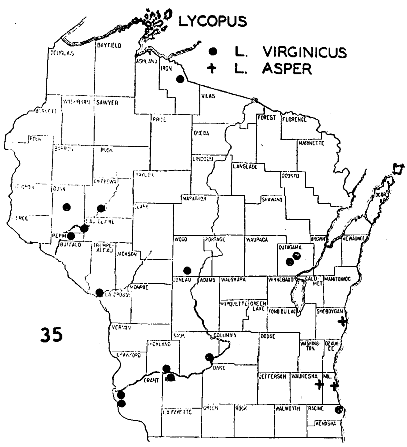

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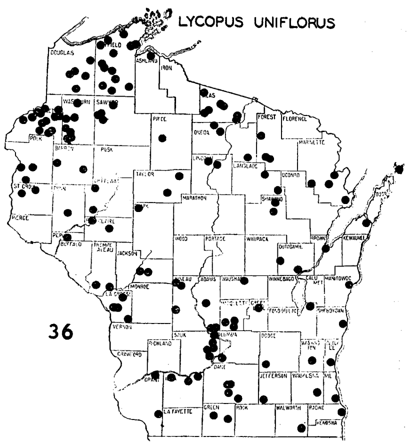


36

21. CLINOPODIUM L. BASIL

[DeWolf. Notes on Cultivated Labiates. Baileya 33:145–150. 1954.]

1. C. VULGARE L. Wild Basil. Map 31.

Satureja vulgaris (L.) Fritsch.

In damp places, especially low woods and along lake shores. Flowering end of June thru September.

22. HYSSOPUS L. HYSSOP

1. H. OFFICINALIS L. Map 32.

Native of Eurasia; occasionally escaping from herb gardens. In sandy soils of old fields, roadsides, and waste places. Not common. Flowering July to October (Gleason, 1952).

23. THYMUS L. THYME

1. T. SERPYLLUM L. Wild Thyme. No map.

Gleason (1952, 3:178) reports this species "Native of Europe; commonly cultivated for ornament . . .". The only Wisconsin collection is from a lawn at Arcadia in Trempealeau County, July 27, 1954, *Comm. F. V. Burcalow s. n.* (WIS).

24. PYCNANTHEMUM MICHX. MOUNTAIN MINT; BASIL

[Grant & Epling. A Study of Pycnanthemum. Univ. Calif. Publ. Bot. 20:195–240. 1943.]

a. Stem glabrous throughout; leaves glabrous, the lower with one or two pairs of lateral veins, all arising near the base .... 1. *P. flexuosum.*

a. Stem pubescent on the angles; leaves scabrous, at least on the margins, the lower usually with four pairs of lateral veins, the terminal pair arising near the middle .... 2. *P. virginianum.*

1. P. FLEXUOSUM (Walt.) BSP. Map 23, crosses.

Native of the eastern and southern United States, in Wisconsin apparently adventive, with small colonies occurring sporadically along beaches, roadsides, or railroad embankments. Flowering July to September (Fernald, 1950).

2. P. VIRGINIANUM (L.) Durand & Jackson. Map 33, dots.

In low prairies, pastures, meadows, ditches, bog and marsh borders, and occasionally in dry prairies or oak-pine woods, mostly in the southern half of the state. Flowering from early July to mid-September.

25. LYCOPUS L. WATER HOREHOUND

a. Calyx teeth narrowly triangular, sharply acuminate, clearly exceeding the mature nutlets.
  b. Lower leaves petioled, usually laciniate; stem not tuberous; ridge of nutlets entire, conspicuous on all three dorsal angles.. 1. *L. americanus.*
  b. All leaves sessile, serrate; stem often with an elongate tuber; ridge of nutlet shallowly undulate, the apical ridge scarcely evident.. 2. *L. asper.*
a. Calyx teeth broadly triangular, obtuse or barely acute, not, or scarcely, exceeding the mature nutlets.
  c. Top of nutlet with many sharp, prominent, tubercles, the side margins usually more or less undulate, the upper half of the dorsal surface rough, the top surface of the 4 nutlets flat: corolla lobes erect, stamens included; leaf margins from the lowest tooth to the stem always concave; main stem usually not tuberous, but the stolons often with tubers. Plants robust, usually large .... 3. *L. virginicus.*
  c. Top of nutlet with about 3–5 shallow, rounded tubercles, the side margins entire or essentially so, the dorsal surface smooth, the top surface of the 4 nutlets concave; corolla lobes spreading, the stamens exserted; leaf margins from the lowest tooth to the stem typically convex or straight, sometimes concave; main stem as well as the stolons tuberous. Plants slender, often small .... 4. *L. uniflorus.*

1. L. AMERICANUS Muhl. Map 34.

Common along lake shores, stream banks, river bottoms, marsh borders, wet prairies, bogs, and any low moist ground throughout the state. Flowering early July through August.

2. L. ASPER Greene. Map 35, crosses.

A western species, occasionally adventive in Wisconsin along railroad tracks and Lake Michigan harbors. Flowering July and August (Fernald, 1950).

3. L. VIRGINICUS L. Map 35, dots.

Uncommon throughout the state; occurring mostly in wooded river bottoms. Flowering July to October (Fernald, 1950).

This species is frequently confused with the next.

4. L. UNIFLORUS Michx. Map 36.

Common on lake shores, stream and river banks, damp fields and meadows, tamarack bogs, cedar swamps, and low woodlands throughout Wisconsin. Flowering mid-July to mid-September.

26. MENTHA L. MINT

a. Flowers in axillary verticils separated by internodes of normal length.
  b. Calyx pubescent throughout .... 1. *M. arvensis.*
  b. Calyx glabrous, or pubescent in the upper half only.
    c. Leaves subtending verticils noticeably reduced in size.. 2. *M. cardiaca.*
    c. Leaves subtending verticils not noticeably reduced in size.. 3. *M. gentilis.*

a. Flowers in terminal spikes or heads, the internodes greatly shortened.
  d. Infloresence a globose head of 1–3 verticils; calyx glabrous .... 4. *M. citrata.*
  d. Inflorescence spike-like, composed of several to many verticils; calyx, or at least the lobes, pilose.
    e. Principal leaves sessile, or with short petioles less than 3 mm. long.
      f. Leaves glabrous or nearly so .... 5. *M. spicata.*
      f. Leaves densely pubescent, especially beneath.
        g. Leaves oblong-lanceolate, 2–3 times as long as wide .... 6. *M. longifolia.*
        g. Leaves ovate, less than twice as long as wide.
          h. Spike slender (excluding corollas, 5 mm. in diameter), tail-like in age; leaves strongly rugose, crenate-dentate .... 7. *M. rotundifolia.*
          h. Spike thicker (excluding corollas, 7 mm. in diameter); leaves not strongly rugose, coarsely open-dentate.. 8. *M. alopecuroides.*
    e. Principal leaves on elongate petioles .... 9. *M. piperita.*

1. M. ARVENSIS L.

Two varieties are distinguishable in Wisconsin.

a. Stem pubescent with recurved hairs mostly less than 1 mm. long .... 1a. *M. arvensis* var. *villosa.*
a. Stem villous with mostly spreading hairs 1 mm. or more long .... 1b. *M. arvensis* var. *lanata.*

1a. M. ARVENSIS L. var. VILLOSA Benth. Map 37, dots.

Common on lake, river, and stream banks, swamps, bogs, and low lands throughout Wisconsin. Flowering end of June to mid-September. This and the following are the only native taxa.

1b. M. ARVENSIS L. var. LANATA Piper. Map 37, diamonds.

Widely distributed throughout the state; habitats and flowering time the same as number 1a.

2. M. CARDIACA Baker. Map 38, dots.

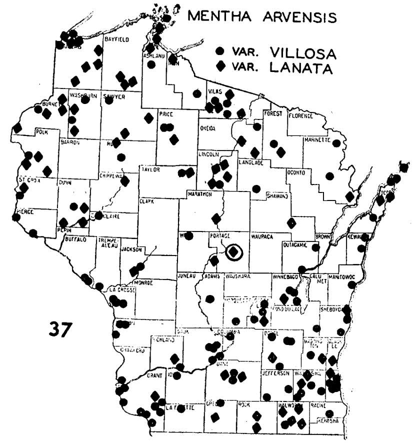
Mostly in the southern part of the state, on lake shores, stream banks, and river bottoms. Introduced from Europe and occasionally escaping from cultivation. Flowering end of July to the end of September.

Gleason (1952, 3:187) states that this species may have arisen by hybridization between *M. arvensis* and *M. spicata.*

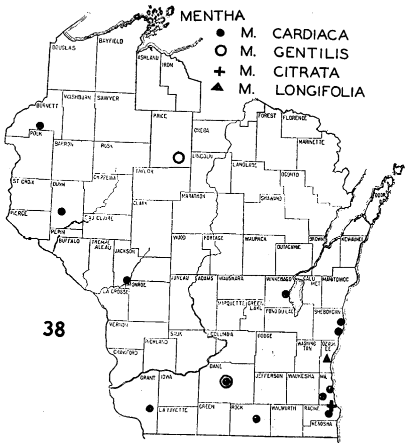
3. M. GENTILIS L. Map 38, circle.

Introduced from Europe; our one specimen collected at Prentice, Aug. 20, 1915, *Chas. Goessl s. n.* (WIS).

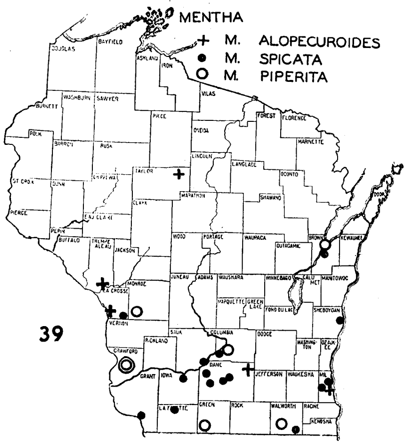
Considered to have originated by hybridization between *M. arvensis* and *M. spicata,* (Gleason, 1952, 3:186).


MENTHA ARVENSIS
● VAR. VILLOSA
◆ VAR. LANATA

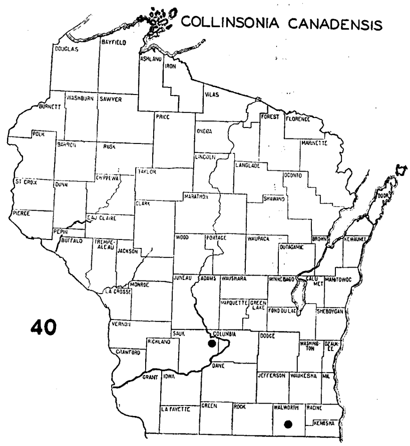
37


MENTHA
● M. CARDIACA
O M. GENTILIS
+ M. CITRATA
▲ M. LONGIFOLIA

38


MENTHA
+ M. ALOPECUROIDES
● M. SPICATA
O M. PIPERITA

39


COLLINSONIA CANADENSIS

40

4. M. CITRATA Ehrh. Map 38, cross.

Introduced from Europe. One specimen collected at Hustler, Sept. 2, 1925, *J. H. Mueller s. n.* (WIS).

Considered to have originated by hybridization between *M. aquatica* and *M. spicata* (Gleason, 1952, 3:187).

5. M. SPICATA L. Spearmint. Map 39, dots.

Native of Europe; commonly cultivated and occasionally escaping. Reported from roadside ditches and creek banks, mostly in the southern half of the state. Flowering mid-July to mid-September.

6. M. LONGIFOLIA L. Map 38, triangle.

Native of Eurasia; three specimens (MIL) collected at Grafton, Ozaukee County, September 2, 1908.

7. M. ROTUNDIFOLIA (L.) Huds. No map.

Native of southern Europe; cultivated in herb gardens. The single Wisconsin collection (MIL) is from a garden at Sheboygan. This species is frequently confused with the next.

8. M. ALOPECUROIDES Hull. Woolly Mint. Map 39, crosses.

Introduced from Europe; collected in Trempealeau, La Crosse, Dane, and Milwaukee Counties, from roadsides and vacant lots. Flowering early August thru September.

9. M. PIPERITA L. Peppermint. Map 39, circles.

Introduced from Europe; frequently cultivated and occasionally escaping along damp roadsides, in bogs, and low meadows. Flowering early August to mid-September.

Considered to have originated by hybridization between *M. aquatica* and *M. spicata* (Gleason, 1952, 3:188).

27. COLLINSONIA L. HORSE-BALM; STONEROOT; RICHWEED

1. C. CANADENSIS L. Map 40.

One of the rarest of the native Wisconsin mints. The two collections (WIS) are: Sauk County, valley of the Wisconsin River near Baraboo, August 1865, *Hale (?) s. n.;* Walworth County, summit of hill, rich woods east of Uniontown (T-2N; R-17E; S-30), August 31, 1940, *J. W. Thomson s. n.*

Deam (1940) shows this species to be common in Indiana; Jones and Fuller (1955) list it for only seven counties, considering it rare in Illinois.

28. ELSHOLTZIA Willd.

1. E. ciliata (Thunb.) Hylander. No map.

Native of Asia; Gleason (1952) reports it established from Quebec to Massachusetts.

The only Wisconsin collection is from a roadside camping area at the north end of Devils Lake State Park, November 2, 1946, *J. H. Zimmerman 1587* (WIS).

29. OCIMUM L. Basil

1. O. basilicum L. No map.

Native of tropical Asia and Africa; rarely escaping from herb gardens. The single Wisconsin collection is from a roadside colony near Mount Horeb, September 15, 1953, *J. W. Thomson s. n.* (WIS). This small colony is known to have persisted for 2 years.

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NOTES ON WISCONSIN PARASITIC FUNGI. XXIII

H. C. GREENE
Department of Botany, University of Wisconsin, Madison

The collections of fungi referred to in this publication were, unless otherwise noted, made during the season of 1956.

PERONOSPORA STIGMATICOLA Raunk. was observed in fair abundance on flowers of *Mentha arvensis* var. *canadensis* in the University of Wisconsin Arboretum at Madison in August. The fungus is not confined to the stigmas, but occurs commonly on the petals as well, and rather rarely on the stamens.

Undetermined powdery mildews have been collected on the following hosts: *Potentilla palustris,* Rocky Arbor Roadside Park, Juneau Co., July 24; *Galium triflorum,* Madison, Dane Co., October 21, 1955; *Aster lindleyanus,* Drummond, Bayfield Co., September 12; *Silphium laciniatum* X *terebinthinaceum,* Madison, Dane Co., October 1; *Artemisia caudata,* Wisconsin Point, Superior, Douglas Co., September 11; *Arctium minus,* Madison, Dane Co., October 25, 1955; *Hieracium aurantiacum,* Augusta, Eau Claire Co., September 10.

Pyrola elliptica, collected in the University of Wisconsin Arboretum at Madison, July 30, bears a sphaeriaceous Ascomycete which I have been unable to determine as to genus. The erumpent perithecia on dark brown, rounded areas on the leaves are amphigenous, mostly epiphyllous, blackish-brown, gregarious, subglobose, ca. 100–200μ diam. The asci measured are from 36–42 x 8–10μ, clavate. Ascospores are limoniform or subfusoid, hyaline, continuous, 10–12 x 4–5μ. Material held for 96 hours in a moist chamber failed to mature further, insofar as any production of septa in the spores was concerned.

AECIDIUM AVOCENSIS Cummins & Greene on *Callirhoe triangulata* and *Puccinia avocensis* Cummins & Greene on *Stipa spartea* were described in these Notes XX (Trans. Wis. Acad. Sci. 43:176–177. 1954) from the same station near Avoca in Iowa Co. On the basis of what is known of the mallow-*Stipa* rust complex it seems more than probable that the two are but life stages of a single rust. Unfortunately, this has not so far been demonstrated. Attempts have been made to infect plants of *Stipa* in the field in the University of Wisconsin Arboretum at Madison, and in the greenhouse of the Botany Department at Madison with negative results. Infected, overwintered *Stipa* leaves were suspended over greenhouse-grown seedlings of *Callirhoe*, under seemingly favorable conditions of temperature and humidity, and mature plants of *Callirhoe* growing in the University Arboretum were mulched with rusted *Stipa* leaves, but no infection occurred in either case.

PUCCINIA TOMIPARA Trel. on *Bromus ciliatus* was based on Wisconsin material collected by Pammel near La Crosse (Trans. Wis. Acad. Sci. 6:127. 1885). The teliospores are remarkable in being multicellular and muriform, with vertical as well as horizontal septa. Arthur, on the basis of aecial infections carried out by W. P. Fraser (Mycologia 11:129–133. 1919), concludes that *P. tomipara* is but a manifestation of *P. rubigo-vera*. G. B. Cummins, however, tells me that he considers *P. tomipara* as probably a valid species, and an examination of Fraser's article shows that he too thought this, since urediospores from *P. tomipara* failed to infect *Elymus*, *Agropyron* and *Hordeum*. Trelease's specimen is in the herbarium of the National Fungus Collections, but specimens on *Bromus ciliatus* in the Wisconsin Herbarium collected at Racine in 1899 and 1903, and at Madison in 1943 and 1945 unquestionably are *P. tomipara*. Other specimens on *Bromus* in our herbarium appear to be *P. rubigo-vera*.

PHYLLOSTICTA sp. occurs on still green leaves of *Adiantum pedatum* collected near Dane, Dane Co., October 4, 1955. The sooty pycnidia are scattered to gregarious, causing no spotting of the leaf. They are subglobose, approx. 75–125μ diam., with a well-marked ostiole. The conidia are hyaline, rod-shaped, 4–6 x 1.5μ. Perhaps the precursor of an ascomycetous stage.

PHYLLOSTICTA sp. was collected May 5, 1955 on leaves of *Erythronium albidum* at two stations in Green Co. (Trans. Wis. Acad. Sci. 45:180. 1956). On May 31, 1956 similar but older material was found in a large stand of the same host at Oakly, Green Co. Many of the leaves were completely blackened by the fungus mycelium. As mentioned in the earlier note, sections show only pycnidia with no evidence of any incipient perfect stage. It seems probable that the heavy mycelium and thick-walled pycnidia are sufficiently resistant to survive until the next spring and, if necessary, produce new conidia at that time to carry on the infection.

PHYLLOSTICTA sp. is present in small amount on leaves of *Corylus americana* collected in the New Glarus Woods Roadside Park, Green Co., August 15. The pale brown spots, with narrow darker border, are irregular, angled to orbicular, approx. 2–5 mm. diam. The pycnidia are epiphyllous, blackish, subglobose, 75–100μ diam., and scattered. The conidia are hyaline, broadly ellipsoid to short-cylindric, 4–7 x 3–3.5μ.

PHYLLOSTICTA sp. has been noted on broadly oval pale gray leaf lesions, about 1 cm. diam., on *Cornus rugosa*, collected at Devils

Lake, Sauk Co., August 24. The epiphyllous pycnidia are scattered, approaching superficial, variable in size, black, subglobose. Conidia are subcylindric, broadly ellipsoid, or ovoid, hyaline, 4–7 x 2.5–3.5μ. This is not far from *Leptothyrium*.

RHYNCOPHOMA (?) sp. occurs on stems and leaves of *Aster pilosus* collected at Madison, October 22. This seems to be better developed material of a specimen on leaves of the same host which was doubtfully referred to *Septoria* in my Notes XX (Trans. Wis. Acad. Sci. 43:169. 1954). In the latter specimen the pycnidial beaks are more strongly developed, particularly in the pycnidia on the stems. The pycnidia are subglobose, about 75–140μ diam., the conidia hyaline, subfusoid to cylindric, 12–18 x 3–3.5μ, uniformly 1-septate. Perhaps parasitic, although it is not possible to be certain, since the late-season material in hand has been frosted.

Cirsium discolor, collected at Madison, October 22, bears a *Pyrenochaeta*-like didymosporous fungus on the hairy undersurface of the leaves. The superficial pycnidia are globose, deep brown, apically setose, about 200–300μ diam. The spores are hyaline, cylindric, 11–18 x 3–4μ, 1-septate. As with similar phragmosporous material on *Cirsium muticum* (Trans. Wis. Acad. Sci. 41:120. 1952) there seems to be in this case no genus of the Hyalodidymae which provides for such a form.

ASTEROMA (?) occurs on *Acer negundo* leaves collected at Tower Hill State Park, Iowa Co., October 13, 1955. The radiate-dendritic black mycelium is quite similar in appearance to that of *Asteroma ribicolum* Ell. & Ev. There are no fruiting bodies present, so assignment to *Asteroma* must be tentative. *Asteroma aceris* Rob. & Desm. has been reported on various species of *Acer* in Europe.

STAGONOSPORA ARENARIA Sacc. on *Oryzopsis racemosa*, collected in the New Glarus Woods Roadside Park, Green Co., August 15, has some pycnidia which bear small, rod-shaped, hyaline microspores, about 3.5–5 x 1.5μ.

STAGONOSPORA sp. occurs on *Lactuca spicata*, collected at Parfrey's Glen, Town of Merrimac, Sauk Co., August 24. The specimen is rather scanty. The few lesions are rounded, dull brown, faintly zonate, approx. 2–3 cm. diam. The pycnidia are zonately distributed, medium brown, 125–150μ diam. The conidia are hyaline, cylindric, obtuse, straight or slightly curved, mostly 3-, occasionally 1-, 2-, and 4-septate. The spots are reminiscent of those produced on *Lactuca* by *Phyllosticta mulgedii* J. J. Davis.

SEPTORIA sp. occurred in small amount on leaves of *Lilium michiganense* collected at Madison, July 14. The pycnidia are epiphyllous and gregarious on tan areas, brown, globose, small, about 75μ diam., with prominent ostiole; spores hyaline, continuous, straight or slightly curved, 15–25 x 1–1.5μ. I have found no report of *Septoria* on *Lilium.*

SEPTORIA PILEAE Thum. is a common parasite of *Pilea pumila* in Wisconsin. The usually rather small pycnidia are on minute, rounded, sharply defined, whitish spots. In mid-October 1955 plants of *Pilea pumila* at Tower Hill State Park, Iowa Co., were noted with large grayish blotches on the leaves. Evenly scattered over the blotches were large, 150–200μ diam., immature, black, globose, subrostrate fruiting bodies which were thought to be probably perithecia. Leaves were overwintered out-of-doors at Madison until May 1956, when examination showed that the typical spores of *Septoria pileae* had been produced in profusion within the fruiting bodies. Production of spores in the spring on sclerotoid bodies, as an over-wintering device, has been noted in a number of cases in the Moniliales, but this is my first experience with such a phenomenon in the Sphaeropsidales. It seems probable that such overwintering, with or without development of an accompanying perfect stage, is a common and highly effective means for perpetuation of many fungi.

SEPTORIA sp. was collected in small amount on *Thlaspi arvense* at Juda, Green Co., May 31. This is close to *Phleospora,* and quite unlike *Septoria thlaspii* Greene (Farlowia 1:575. 1944) which has much narrower spores. In the present specimen the spores are from about 32–45 x 2.5–4μ, 1–3-septate, and except for being somewhat larger are rather similar to those of *S. lepidiicola* Ell. & Mart. on the closely related *Lepidium.*

SEPTORIA sp. occurred on *Desmodium nudiflorum*, collected at Parfrey's Glen, Town of Merrimac, Sauk Co., August 24. The orbicular spots are .7–1 cm. diam., with tan centers and narrow brownish borders. The pycnidia are gregarious, yellow-brown, subglobose, approx. 100–125μ diam. The spores are hyaline, faintly multiseptate, tapered at both ends, from almost straight to strongly crescent-curved, about 20–30 x 1.5μ. There seems to be no report of *Septoria* on *Desmodium.*

SEPTORIA (?) sp. is on leaves of *Aralia hispida* collected near Mather, Juneau Co., July 24. The black, gregarious, almost superficial pycnidia are somewhat collapsed, hypophyllous on dark, angled spots, strongly pseudoparenchymatous, about 115–125μ diam. The spores are hyaline, acicular, flexuous, mostly continuous, but some appearing faintly multiseptate, 55–75 x 1.5μ.

SEPTORIA sp. is borne on sordid spots on leaves of *Monarda fistulosa,* collected by J. J. Davis near Mazomanie, Dane Co., June 12, 1931. The inconspicuous pycnidia are epiphyllous, innate to sometimes rather prominent, 120–175μ diam. The hyaline spores are extruded in cirrhi, are indistinctly septate, mostly rather strongly curved, 40–80 x 2.5–3μ. This may well be *Septoria lophanthi* Wint., judging from comparison with Wisconsin specimens on *Agastache scrophulariaefolia* and with Rabenhorst–Winter's Fungi europaei No. 2991 on *Agastache nepetoides*. Additional confirmatory material would be desirable for a more positive determination.

SEPTORIA EUPATORII Rob. & Desm. occurs in an interesting association with *Puccinia eleocharidis* Arth. I on leaves of *Eupatorium perfoliatum*, collected at Madison, August 11. The old, rounded rust spots are encircled by a broad band of dead brown tissue studded with numerous pycnidia of the *Septoria*. Non-rusted leaves of the same plants also bear *Septoria*, but here it is on tiny cinereous spots with a reddish border, one or two pycnidia per spot, and seeming to behave as a vigorous parasite, whereas such parasitism might seem doubtful where the fungus is adjacent to the old rust sori. However, there seems little doubt that only a single *Septoria* is concerned.

SEPTORIA ATROPURPUREA Peck, on various species of *Aster* and *Solidago*, produces highly characteristic blackish-purple lesions on some hosts, e.g., *Aster macrophyllus* and *A. laevis*. Leaves of *Aster lindleyanus* bearing these lesions were collected at Drummond, Bayfield Co., September 12. Examination of the numerous "pycnidia", however, revealed no typical *Septoria* spores, but micro-conidia in most and undifferentiated contents in others. As much as three weeks previous there had been frosts in this area, and it seems possible that low temperatures caused the fungus to produce overwintering structures instead of typical pycnidia and spores.

SEPTORIA sp. occurs on basal rosette leaves of *Aster shortii*, collected at Oakly, Green Co., October 16. The small, black pycnidia are scattered on large, conspicuous, wedge-shaped tan lesions. The spores are hyaline, mostly strongly curved or bent boomerang-like, occasionally almost straight, continuous or indistinctly septate, 18–28 x 1.5–2.5μ. This does not seem to correspond with any of the three species of *Septoria* reported on *Aster shortii* in Wisconsin, particularly in the sort of lesion produced. However, it is a late-season collection, following a couple of severe early frosts and may thus possibly be an abnormal manifestation of one of these reported species.

SEPTORIA CHRYSANTHEMELLA Cav. and *Septoria chrysanthemi* Allesch. are, judging from collections of *Septoria* made on *Chrysanthemum* in Wisconsin and from specimens available for study in the University of Wisconsin Herbarium, probably identical, representing at most more or less distinct members of an intergrading series.

RHABDOSPORA sp. occurred in an immature development on conspicuous lesions on still-living stems of *Erigeron annuus* at Madison in October 1955. This material was overwintered out-of-doors and brought in for examination in May 1956. The fruiting bodies were still immature, so the stems were placed in a moist chamber for 48 hours, when the fungus was found to have developed satisfactorily. The large black pycnidia are 200μ or more in diam., noticeably erumpent, pseudoparenchymatous, with the ostiole outlined by a ring of heavy, dark cells. The acicular, hyaline spores are approx. 25–45 x 1–1.5μ. Possibly parasitic in its early stage.

SPHACELOMA sp., in scanty amount, was observed on leaves of *Cornus alternifolia* at Madison, August 11. What relation, if any, this bears to *Elsinoe corni* Jenkins & Bitancourt is uncertain. The small spots are ashen with a reddish border, the conidiophores hyaline, 10–12 x 3.5μ, the conidia hyaline, broadly ellipsoid or short-cylindric, 2.5–3.5 x 4.5–7μ.

SPHACELOMA sp., to judge from the characteristic scurfy lesions, is associated with *Septoria xylostei* Sacc. & Wint. on *Lonicera oblongifolia,* collected September 11 at Riverside, Burnett Co. The olivaceous fungus on cinereous lesions closely resembles other species of *Sphaceloma* in gross appearance, but conidia could not be found.

RAMULARIA MAGNUSIANA (Sacc.) Lind. on *Trientalis borealis (americana),* collected July 12 in Point Beach State Forest near Two Rivers, Manitowoc Co., very closely corresponds to Saccardo's original description of the organism as *Septocylindrium magnusianum* and also closely matches the figure of the same in Fungi ital. del. No. 912, with almost obsolete basally inflated conidiophores, and cylindric, 1-septate conidia 20–25 x 4μ. Davis (Trans. Wis. Acad. Sci. 22:167. 1926), on the other hand, assigned a specimen collected at Prentice, Price Co., to *R. magnusiana* that "bears conidia that are seldom septate, 10–33 x 1½–3μ, the shorter ones fusoid. The conidiophores spring from scattered black tubercles 25–40μ in diameter and are mostly fuligenous tinted, 20–60 x 2–3μ . . . . While this departs widely from the type it nevertheless appears to be a variant of that parasite."

FUSICLADIUM (?) sp. occurred on leaves of *Celtis occidentalis* collected at Tower Hill State Park, Iowa Co., October 13, 1955. The fungus is epiphyllous on yellowish-brown orbicular spots which are frequently confluent, involving large portions of the leaf. The fascicles are gregarious in rounded groups of limited diam, on the spots as a rule, but some occur on still green tissue adjacent to the spots. There are mostly a dozen or so conidiophores per fascicle. They are fuscous, septate, subclavate, often curved outward and upward from the base, approx. 40–60 x 5–6μ. The few conidia seen were brownish, somewhat smoky, uniseptate, subfusoid, 23–26 x 6–7μ. I find no record of *Fusicladium* on *Celtis*, but the material in hand is not suitable for descriptive purposes.

CURVULARIA LUNATA (Wakker) Boedijn was reported as parasitizing *Polygala verticillata* in Wisconsin (Amer. Midl. Nat. 48:53. 1952). J. A. Parmelee (Mycologia 48:558–67. 1956) in an article on "The identification of the *Curvularia* parasite of *Gladiolus*" points out that *Curvularia trifolii* (Kauffm.) Boedijn has often been confused with *C. lunata*. He states that the most distinctive feature of *C. trifolii* is the protruding hilum of the spore, as opposed to an inserted hilum in *C. lunata*. It is evident that the Wisconsin specimen must be referred to *C. trifolii*.

CERCOSPORA MISSISSIPPIENSIS Tracy & Earle on *Smilax hispida* seems to be the only species of *Cercospora* collected up to now on *Smilax* in Wisconsin, judging from the treatment in Chupp's "Monograph of Cercospora". Reports of *C. petersii* (B. & C.) Atk. and *C. smilacis* Thum. must be discarded, the latter because of probable misdetermination of the host.

CERCOSPORA, so far not identified, was collected on *Oenothera biennis* at Madison, August 19. The spots are rounded, 1.5–3 mm. diam., sordid grayish, somewhat sunken, with elevated reddish border; conidiophores amphigenous in loose tufts of 5–10 or a few more, multiseptate, clear brown, somewhat lax and flexuous, 2–3-geniculate with conspicuous spore scars, 110–160 x 3.5–4.5μ; conidia hyaline, narrowly obclavate, base truncate with noticeable scar, 5–7-septate, about 50–100 x 3.5–4.5μ. Of the three species of *Cercospora* listed in Chupp's monograph as occurring on *Oenothera* none has conidiophores as long and the Wisconsin specimen differs in other particulars as well.

CERCOSPORA sp. occurred on *Galeopsis tetrahit* at Madison, August 19. The spots are rounded, very small, .7–1.2 mm. diam., pale brown in center, with narrow, darkish-brown, elevated border; conidiophores 10–12 in small tufts, amphigenous, pale brown, subflexuous, several-septate, mildly geniculate, with paler, somewhat clavate tips, up to 190 x 4–5μ; conidia hyaline, slender-obclavate, base truncate, multiseptate, approx. 50–60 x 3–3.5μ. The material is quite limited and insufficient for really thorough examination. It seems possible that the phores observed had undergone some secondary proliferation and may normally be shorter. *Galeopsis* is not among the Labiatae listed as bearing species of *Cercospora*. In grosser characters especially, the specimen bears points of resemblance to *Cercospora isanthi* Ell. & Kell.

CERCOSPORA sp. collected on *Rudbeckia laciniata*, at a station near Juda, Green Co., October 11, 1955, matches *C. tabacina* Ell. & Ev., the only species reported on *Rudbeckia,* fairly well in microscopic characteristics, but is very different in having the fruiting confined to small, rounded, ashen spots, rather than in effuse patches of indefinite extent. It seems probable that exogenous fungi like the Cercosporae may be strongly affected in their development by the relatively cold nights of fall, alternating with warm days, and that this happened in the present case.

ERIOMYCOPSIS sp., so determined by S. J. Hughes of the Canadian Science Service, has been collected in both 1955 and 1956 on living leaves of *Pedicularis lanceolata* at Parfrey's Glen, Town of Merrimac, Sauk Co. While parasitism is perhaps not certain, the very fact that the organism has been found in successive years under the same conditions would seem to indicate a definite relationship between the fungus and the plant on which it is growing. It is hypophyllous in effuse gray patches and there is no spotting and only slight discoloration of the leaf tissue. The fungus seems to be rather closely associated with the trichomes, tending to overrun them. The conidiophores arise from a more or less superficial mycelium and are quite irregular in their development, being frequently quite long, sometimes branched, flexuous to subgeniculate, indistinctly septate, spore scars numerous, prominent, appearing pedicellate, tending to be ranged for considerable distances along the side of the phores. The subhyaline conidia are obclavate with a conic base, often strongly curved, 50–100 x 4.5–7μ, 3–7-septate.

ALTERNARIA sp. on fruiting heads of *Anemone virginiana* was collected at Madison, October 21, 1955. It is evidently the same as a collection on the heads of *Anemone cylindrica,* commented upon in my Notes XVI (Amer. Midl. Nat. 48:747. 1952). Whether the fungus is actively parasitic or not, the set of good seed has been considerably reduced.

A phanerogamic specimen of *Lycopus uniflorus,* collected by N. C. Fassett, September 26, 1936, on the shore of Mason Lake at Briggsville, Adams Co., bears a Pyrenomycete on and in the inflorescence which has been almost completely metamorphosed by the fungus. This organism is obviously parasitic and apparently highly specific. The black, coriaceous perithecia are characteristic of the Sphaeriaceae. The asci, unfortunately, are immature, but from their overall aspect and dimensions it seems likely that this fungus belongs to the Hyaloscoleciae. Paraphyses are numerous and conspicuous.

Solidago nemoralis, collected at Madison, June 19, bears a sphaeropsidaceous fungus, possibly parasitic, but so far not identified to my satisfaction. It is hypophyllous on small, angled, purplish spots. The black, globose pycnidia are superficial, or nearly so, about 100μ diam., rostrate, with the beak about 15–18 x 30–35μ.

The hyaline scolecospores appear mostly 3-septate, are strongly crescentic-curved, 21–30 x 2–2.5μ, tapered at the ends. Using the beak as a diagnostic character, the fungus keys out to *Cornularia* Sacc., but specimens available for comparison are coarse saprophytes on stems of woody plants, and quite unlike this.

ADDITIONAL HOSTS

The following hosts have not been previously recorded as bearing the fungi mentioned in Wisconsin.

UROPHYLCTIS PLURIANNULATA (B. & C.) Farl. on *Zizia aptera.* Waukesha Co., near Eagle, June 14.

PERONOSPORA HYDROPHYLLI Waite on *Ellisia nyctelea.* Dane Co., Madison, May 15.

SPHAEROTHECA HUMULI (DC.) Burr. on *Humulus americanus.* Green Co., near Belleville, August 3. An earlier report on *Humulus americanus* appears actually to have been on *H. japonicus,* as pointed out in my Notes XV (Amer. Midl. Nat. 48:44. 1952).

SPHAEROTHECA HUMULI var. FULIGINEA (Schl.) Salm. on *Matricaria matricarioides.* Dane Co., Madison, October 21.

MICROSPHAERA ALNI (Wallr.) Wint. on *Syringa amurensis.* Dane Co., Madison, October 21, 1955. On *Symphoricarpos occidentalis.* St. Croix Co., Baldwin, September 10, 1956. It appears that this collection represents a mixture of *M. alni* and *M. diffusa,* the latter previously reported on *S. occidentalis.*

ERYSIPHE POLYGONI DC. on *Polygonum achoreum.* Columbia Co., near Okee, October 3. Host determination based on the treatment in the most recent edition of Britton & Brown. Not previously differentiated in these lists from *Polygonum erectum.* On *Ranunculus septentrionalis.* Green Co., Oakly, October 16. On *Delphinium virescens.* Dane Co., Madison, October 21. Coll. J. T. Curtis on plants that had been transplanted in July 1956 from Trempealeau, Trempealeau Co.

ERYSIPHE CICHORACEARUM DC. on *Ambrosia psilostachya.* Eau Claire Co., Eau Claire, September 10. On *Matricaria matricarioides.* Dane Co., Madison, October 18.

ERYSIPHE GALEOPSIDIS DC. on *Scutellaria lateriflora.* Iowa Co., Tower Hill State Park, October 13, 1955. In my Notes VIII (Trans. Wis. Acad. Sci. 38:227. 1946) I deleted *E. galeopsidis* as a parasite of *S. lateriflora* because all specimens from Wisconsin so labeled had the characteristic asci and mature spores of *Erysiphe cichoracearum* DC. The present collection shows large, apparently fully mature perithecia with golden-yellow contents, with asci poorly defined or not evident, and no spores at all.

PARODIELLA PERISPORIOIDES (B. & C.) Speg. on *Desmodium canadense*. Waukesha Co., near Eagle, July 23, 1938. Coll. J. T. Curtis. This material is in excellent maturity and confirms the presence of this species in Wisconsin, concerning which the late J. J. Davis had expressed doubts. Trelease (Trans. Wis. Acad. Sci. 6:10. 1885) reported this tentatively on *Desmodium acuminatum* from La Crosse and stated that the fruiting bodies were pycnidia rather than perithecia. I have examined the Trelease specimen, now in the Herbarium of the National Fungus Collections, and I failed to find mature fruiting of any sort. In employing this name rather than *Parodiella grammodes* (Kze.) Cke., as do Ellis and Everhart, I have followed the usage of Theissen and Sydow in their discussion of the genus *Parodiella* which is in Annal. Mycol. 15:125. 1917.

MYCOSPHAERELLA SPLENIATA (C. & P.) House on overwintered leaves of *Quercus macrocarpa*. Dane Co., Madison, May 17. The occurrence of this species on *Quercus bicolor* has been discussed in my Notes XXI (Trans. Wis. Acad. Sci. 44:39. 1955).

RHYTISMA SALICINUM (Pers.) Fr. on *Salix humilis*. Oneida Co., Minocqua, August 21, 1919. Coll. J. J. Davis. Inadvertently filed in the herbarium under *Rhytisma acerinum*, where it was not noticed until recently.

MELAMPSORA ABIETI-CAPREARUM Tub. II on *Salix* (cult. French hybrid). Dane Co., Madison, September 3.

PUCCINIA ATROFUSCA (Dudl. & Thomp.) Holw. I on *Artemisia serrata*. Pepin Co., Sect. 32, Town of Albany, June 27. The first report on *A. serrata*, although the rust has been collected on numerous species of *Artemisia* farther west. Also the first collection of aecial material in Wisconsin. Arthur determined a uredial-telial specimen on *Carex oligocarpa* from Two Rivers, Manitowoc Co., as *P. atrofusca*. It is of interest that the corresponding microcyclic form, *P. millefolii* Fckl., has been collected on *Artemisia frigida* at Stockholm, also in Pepin Co.

PUCCINIA HELIANTHI Schw. II, III on *Helianthus hirsutus*. Dane Co., Madison, August 20.

CERATOBASIDIUM ANCEPS (Bres. & Syd.) Jacks. on *Sanguinaria canadensis*. Waukesha Co., near Big Bend, July 11. On *Osmorhiza claytoni*. Vernon Co., Coon Valley, June 29.

XENOGLOEA ERIOPHORI (Bres.) Syd. on *Scirpus rubrotinctus*. Juneau Co., near Union Center, June 27.

PELLICULARIA FILAMENTOSA (Pat.) Rogers on *Hieracium longipilum*. Dane Co., Madison, August 17.

PHYLLOSTICTA QUERCUS Sacc. & Speg. on *Quercus ellipsoidalis*. Burnett Co., Crex Meadows near Grantsburg, September 11.

PHYLLOSTICTA VIRGINIANA (Ell. & Halst.) Seaver on *Prunus americana*. Dunn Co., Falls City, September 10. The pycnidia are mostly epiphyllous on this host.

PHYLLOSTICTA CACALIAE H. C. Greene on *Cacalia tuberosa* X *atriplicifolia*. Dane Co., Madison, August 13.

PHYLLOSTICTA FAVILLENSIS H. C. Greene on *Helianthus rigidus (laetiflorus)*. Dane Co., Madison, August 1. Hitherto collected only on *Silphium integrifolium*. The fungus seems entirely characteristic, although on the narrow leaves of *H. rigidus* the spots are smaller, with only one to a few pycnidia per spot.

PHYLLOSTICTA MULGEDII J. J. Davis on *Lactuca canadensis*. Dane Co., Madison, August 25, 1955.

ASCOCHYTA EQUISETI (Desm.) Greene on *Equisetum hyemale*. Sheboygan Co., Terry Andrae State Park, July 12.

ASCOCHYTA COMPOSITARUM J. J. Davis on *Krigia biflora*. Dane Co., Madison, June 20. This is the small-spored form, once set aside by Davis as var. *parva*, as discussed in my Notes X (Amer. Midl. Nat. 39:449. 1948). The variety seems well-defined and perhaps should be retained.

DARLUCA FILUM (Biv.) Cast. on *Uromyces holwayi* III on *Lilium michiganense*. Dane Co., Madison, July 14.

STAGONOSPORA SIMPLICIOR Sacc. & Berl. f. *andropogonis* Sacc. on *Calamagrostis canadensis*. Dane Co., Madison, August 9. Another in the series discussed in my Notes XV (Amer. Midl. Nat. 48:51. 1952). On this host the quite characteristic spores are somewhat larger than any others so far seen, running 40–55 x 12–15μ, 3-septate and 4-guttulate, broadly fusoid or subcylindric. The pycnidia occur in great profusion on dead lower leaves of still living host plants.

STAGONOSPORA THASPII (Ell. & Ev.) Greene on *Osmorhiza longistylis*. Rock Co., Leyden, May 31.

SEPTORIA PASSERINII Sacc. (microsporous) on *Cinna arundinacea*. Iowa Co., Tower Hill State Park, October 13, 1955. Also on *Elymus virginicus*. Dane Co., near Belleville, September 13, 1952. This specimen was erroneously determined as *Selenophoma donacis* var. *stomaticola* (Trans. Wis. Acad. Sci. 43:175. 1954). A report of *Selenophoma everhartii* on *Hystrix patula* (Trans. Wis. Acad. Sci. 41:124. 1952) appears also to have been based on microsporous *Septoria passerinii*, previously listed on *Hystrix* in Wisconsin.

SEPTORIA AQUILEGIAE Penz. & Sacc. on *Aquilegia falbellata* var. *nana* (hort. dwarf). Dane Co., Madison, September 3. Coll. J. T. Curtis.

SEPTORIA PSILOSTEGA Ell. & Mart. on *Galium concinnum*. Sauk Co., Parfrey's Glen, Town of Merrimac, October 3.

SEPTORIA CIRSII Niessl on *Carduus nutans*. Walworth Co., near Troy Center, June 14.

SEPTORIA ASTERICOLA Ell. & Ev. on *Aster lucidulus*. Dane Co., Madison, June 8. Assigned to this species largely on the basis of the host. As I have stated in earlier notes, it seems quite likely that this species and *Septoria fumosa* Peck, usually considered to occur on various species of *Solidago,* are not really distinct.

SEPTORIA LACTUCICOLA Ell. & Mart. on *Lactuca floridana*. Green Co., New Glarus Woods Roadside Park, August 15. *S. lactucicola* is separated from *S. lactucae* Pass. chiefly by the more sharply defined lesions in the former, a distinction of dubious validity.

SELENOPHOMA EVERHARTII (Sacc. & Syd.) Sprague & Johns. on *Aristida basiramea*. Dunn Co., Falls City, September 10. Det. confirmed by Sprague. *Selenophoma donacis* var. *stomaticola* was reported on both *Aristida basiramea* and *A. tuberculosa* in an earlier publication, the determination being based on the quite robust spores which seemed more in the range of *S. donacis* var. *stomaticola* than of *S. everhartii*. It is possible, however, that all are the same.

HAINESIA LYTHRI (Desm.) Hoehn. on *Oenothera biennis*. Dane Co., Madison, July 27.

MARSSONINA VIOLAE (Pass.) Magn. on *Viola papilionacea*. Dane Co., Madison, September 3. Coll. J. H. Zimmerman.

LEPTOTHYRIUM SIMILISPORUM (Ell. & Davis) Davis on *Solidago missouriensis*. Iowa Co., near Muscoda, July 18; also near Falls City, Dunn Co., September 10.

COLLETOTRICHUM URTICAE H. C. Greene on *Laportea canadensis*. Vernon Co., Coon Valley, June 29. The tips of the setae are somewhat more acute than in the type on *Urtica,* but otherwise the specimen is very similar, including the characteristic straight conidia.

COLLETOTRICHUM LAGENARIUM (Pass.) Ell. & Halst. on *Citrullus vulgaris*. Monroe Co., Tomah, July 5, 1913. Coll. Reynolds. (From collections of the Dept. of Plant Pathology, Univ. of Wis.)

CYLINDROSPORIUM ARTEMISIAE Dearn. & Barth. on *Artemisia caudata*. Douglas Co., Wisconsin Point, Superior, September 11.

MONOCHAETIA DISCOSIOIDES (Ell. & Ev.) Sacc. on *Rosa* sp. Dane Co., Madison, August 7, 1955. The rose is one of our native species, but bore neither flowers nor fruit. Although perhaps only dubiously parasitic, the fungus is on well-defined rounded or wedge-shaped spots on otherwise apparently healthy leaflets.

THIELAVIOPSIS BASCICOLA (B. & Br.) Ferraris on *Panax quinquefolium*. Langlade Co., Antigo, August 1911. Coll. & det. J. Rosenbaum (From collections of the Dept. of Plant Pathology, Univ. of Wis.).

PIRICULARIA GRISEA (Cke.) Sacc. on *Setaria verticillata*. Dane Co., Madison, August 19. This host evidently has considerable resistance, as it has often been examined on other occasions without finding any fungus on it. The infection was quite light, although the host was growing mingled with plants of *Setaria viridis* which were heavily infected.

CLADOSPORIUM ASTERICOLA J. J. Davis on *Parthenium integrifolium*. Dane Co., Madison, August 10. Hitherto reported only on *Aster* and *Solidago*. Infected plants of *Solidago speciosa* were closely adjacent.

CERCOSPORA MUHLENBERGIAE Atk. on *Muhlenbergia schreberi*. Sauk Co., Parfrey's Glen, Town of Merrimac, October 3. Chupp does not regard this as being a good *Cercospora*, but it is an entity, and until it is placed elsewhere I so refer it.

CERCOSPORA STOMATICA Ell. & Davis on *Solidago graminifolia*. Green Co., near Albany, August 3.

CERCOSPORA WISCONSINENSIS Chupp & Greene on *Prenanthes crepidinea*. Green Co., near Juda, August 15.

TUBERCULINA PERSICINA (Ditm.) Sacc. on *Tranzschelia thalictri* on *Thalictrum dasycarpum*. Dane Co., Madison, July 3. Not particularly obvious, except for the characteristic purplish color, as the fungus, instead of being elevated, is somewhat sunken or at most level with the mouths of the host sori which are poorly developed. Also on *Puccinia liatridis* I on *Liatris pycnostachya*. Waukesha Co., Saylesville, July 11.

BRIOSIA AMPELOPHAGA Cav. on *Vitis aestivalis*. Sauk Co., Parfrey's Glen, Town of Merrimac, August 24.

ADDITIONAL SPECIES

The fungi mentioned have not been previously reported as occurring in the state of Wisconsin.

Mycosphaerella thaspiicola sp. nov.

Cercospora thaspiicola J. J. Davis. Trans. Wis. Acad. Sci. 24:291. 1929.

Cercospora cordatae Chupp & Greene. Trans. Wis. Acad. Sci. 36: 265. 1944.

Peritheciis hypophyllis, arcte gregariis, nigris, globosis, ca. 105–125μ diam.; ascis tenuo-clavatis, ca. 50–60 x 10–12μ; ascosporis hyalinis, septis mediis, fusoideis, 24.5–27.5 x 4.5–6μ.

Perithecia hypophyllous, closely gregarious, black, globose, approx. 105–125μ diam.; asci slender-clavate, approx. 50–60 x

10–12μ; ascospores hyaline, septum median, fusoid, 24.5–27.5 x 4.5–6μ.

In September 1955 leaves of *Zizia aurea* in the University of Wisconsin Arboretum at Madison were noted to be heavily infected with *Cercospora thaspiicola* J. J. Davis. This fungus is produced on characteristically diffuse, rather inconspicuous lesions on the under sides of the leaves. A month later the lesions were re-examined and were found to be closely studded with immature, black, globose structures which had developed in the tissue under the old *Cercospora* fruiting. Many conidia and phores were still present. On October 19, 1955 a number of these leaves were placed in a screen cage and overwintered out-of-doors until May 15, 1956. There seems no doubt as to the connection between the *Cercospora* and the *Mycosphaerella* stages, for the overwintered leaves bear not only mature perithecia, but closely associated with or on them are numerous conidiophores and conidia of *Cercospora thaspiicola.* The phenomenon of conidial production on fall-formed perithecium-like bodies following overwintering is rather common, but I have not hitherto in any other case detected simultaneous development of a mature perfect stage. The *Cercospora* stage has also been found in Wisconsin on *Thaspium trifoliatum* var. *flavum (T. aureum)* and on *Zizia aptera (cordata)*.

MYCOSPHAERELLA CHIMAPHILAE (Ell. & Ev.) Hoehn. on *Chimaphila umbellata.* Sauk Co., Parfrey's Glen, Town of Merrimac, August 24. This fungus has often been noted, but previous specimens have failed to show any mature asci and spores, which are sparingly present in this material.

Elsinoe wisconsinensis sp. nov.

Maculis nullis; frondibus sordido-flavidis vel discoloris aliter; stromatibus canis, crustaceo-convolutis, elevatis modice, crassitudinibus usque 100μ vel leviter amplius, plerumque parvis, rotundatis vel elongatis irregulariter, saepe confluentibus, amphigenis et in petiolis et stipitibus; ascis loculatis, subglobosis, late ellipsoideis vel ovoideis, ca. 15–25μ diam., potius propinque irregulariterque in stromatibus; ascosporis hyalinis, cylindraceis, 3-septatis, 10–12 x 4–4.5μ; conidiophoris plerumque unicis in stromatibus, hyalinis, simplicibus et continuis, rectis vel curvis leviter, apicibus constrictis aliquoties, 10–17 x 2.5–3.5μ; conidiis hyalinis, ellipsoideis vel ovoideis, 4–7 x 2.5–3.5μ.

Spots none; leaves becoming sordid yellowish or otherwise discolored; stromata grayish, crustose-convolute, moderately elevated, up to 100μ thick or slightly more, mostly rather small, irregularly rounded or elongate in outline, often confluent, amphigenous and on petioles and stems; asci loculate, subglobose, broadly ellipsoid or ovoid, approx. 15–25μ diam., rather closely and irregularly distributed throughout the stromata; ascospores hyaline, cylindric, 3-septate, 10–12 x 4–4.5μ; conidiophores produced mostly singly and rather sparingly over the stromatic surface, hyaline, simple and continuous, straight or slightly curved, sometimes constricted near tip, 10–17 x 2.5–3.5μ; conidia hyaline, ellipsoid or ovoid, 4–7 x 2.5–3.5μ.

On living leaves, petioles and stems of *Desmodium illinoense*. Coll. at Madison, Dane County, Wisconsin, U. S. A., August 29, 1953. Other specimens are from near Brodhead, Green Co., Delavan, Walworth Co., and from Lafayette Co. near Platteville. A specimen was collected at Exeter, Green Co., on a plant tentatively identified as *Desmodium canadense,* but this is uncertain because of the host immaturity. This fungus has been observed several years consecutively at Madison and is probably widespread in southern Wisconsin, where it was first collected in 1951 in Lafayette Co. (Trans. Wis. Acad. Sci. 41:122. 1952; 43:166. 1954).

The conidial phase, here designated as **Sphaceloma wisconsinensis,** is quite transient. The delicate conidiophores arise singly, or rarely in twos or threes, and are rather widely scattered, so that relatively small numbers of conidia, which soon fall away, are produced. A specimen collected at Madison, July 7, 1956, showed conidia and phores particularly well and has been placed in the herbarium.

As the stromata become older later in the season, the closely compacted, rather thick-walled component hyphae become darker, until eventually the stromata become dull black. The effect of the infection on the host is sometimes quite striking, causing stunting both in height and in leaf dimension, premature leaf-fall, and death of the above-ground portion of the plant.

CERATOSTOMELLA ULMI Buisman on *Ulmus americana*. The Dutch Elm Disease was first reported in Wisconsin July 6, 1956 at Beloit, Rock Co., and soon after from Kenosha, Racine, Milwaukee and Walworth counties. It seems probable that the disease will soon be detected in all the southern tier of counties.

PHYLLOSTICTA MOLLUGINIS Ell. & Halst. on *Mollugo verticillata*. Columbia Co., near Lodi, July 25. *Cercospora molluginis* Halst. is also present.

PHYLLOSTICTA ALLANTOSPORA Ell. & Ev. on *Thlaspi arvense*. Rock Co., near Footville, May 10. This corresponds closely with type material on *Cakile edentula (americana)* from the herbarium of F. L. Stevens. Although in the description in North American Flora the pycnidia are stated to be 100–110μ diam., I find them to be about 150–200μ in both the type and the Wisconsin specimen.

It seems possible that *Phyllosticta brassicicola* McAlp. and *P. allantospora* are identical. If so, the latter is the older name.

Phyllosticta hydrophylli sp. nov.

Maculis fuscis, centris pallidioribus, orbicularibus, .3–1.5 cm. diam., saepe confluentibus; pycnidiis pallido-brunneis, pellucidis, immersis, sparsis, plerumque paucis in centris maculis, subglobosis vel late ellipticis, 75–160μ, plerumque ca. 100–125μ diam., ostiolatis; conidiis hyalinis, bacilliformibus, 5–8 x 1.5–2μ.

Leaf spots blackish-brown, with somewhat paler centers, orbicular, .3–1.5 cm. diam., often confluent; pycnidia pale brownish, translucent, innate, scattered, mostly few in central parts of spots, subglobose or broadly elliptic, 75–160μ, mostly about 100–125μ diam., ostiolate; conidia hyaline, bacilliform, 5–8 x 1.5–2μ.

On living leaves of *Hydrophyllum appendiculatum.* Coon Valley, Vernon County, Wisconsin, U. S. A., June 29, 1956.

I have not discovered any previous reports of *Phyllosticta* on *Hydrophyllum.* The spots are very conspicuous, one to several per leaf, or where confluent sometimes involving almost the entire leaf. The pycnidial wall is very thin, but entire, with a well-marked ostiole.

Ascochyta ribicola sp. nov.

Maculis orbicularibus vel lobulatis, 4–8 mm., plerumque 5–7 mm. diam., pallido-brunneis vel sordidis, cum marginibus angustis fuscis, plusve minusve distincte zonatis; pycnidiis pallido-carneis, muris tenuibus, sparsis vel gregariis, subglobosis, ca. 90–160μ diam.; conidiis hyalinis, septis mediis, brevo-cylindraceis vel subfusoideis, 7–11 x 3–4.5μ.

Leaf spots orbicular or somewhat lobed, 4–8 mm., mostly 5–7 mm. diam., tan or grayish with a narrow fuscous border, more or less distinctly zonate; pycnidia pale flesh-colored, thin-walled, epiphyllous, scattered or gregarious, subglobose, approx. 90–160μ diam.; conidia hyaline, median septum, short-cylindric or subfusoid, 7–11 x 3–4.5μ.

On living leaves of *Ribes americanum.* University of Wisconsin Arboretum, Madison, Dane County, Wisconsin, U. S. A., July 7, 1956.

In my Notes XX (Trans. Wis. Acad. Sci. 43:178. 1954) I described *Phyllosticta succinosa* on *Ribes americanum.* Macroscopically this is quite suggestive of *Ascochyta ribicola,* but microscopically the resemblance is much less evident and it is a question as to whether the two are related. Re-examination of the type of *P. succinosa* shows no septate spores, so far as observed, and the size range barely overlaps (4–7 x 2.5–3μ for *P. succinosa*).

SEPTORIA MATRICARIAE Hollos on *Matricaria matricarioides.* Jackson Co., City Point, July 24. Hollos described this species in 1910 on *Matricaria discoidea,* while Sydow, evidently overlooking the Hollos name, applied the same name to a fungus on *Matricaria chamomilla* (Annal. Mycol. 19:143. 1921). Hollos described the pycnidia as being 100–130μ diam. and the conidia as 40–60 x 2–2.5μ, while Sydow gives the pycnidia as 50–70μ diam. and the spores as 30–60 x 1–1.5μ. My specimen is intermediate, suggesting that Hollos' and Sydow's fungi may represent the extremes of a series.

Cylindrosporium vaccinii sp. nov.

Maculis fuscis, angulatis, 2–3 mm. diam., saepe confluentibus; acervulis epiphyllis, sparsis vel gregariis, ca. 40–70μ diam.; conidiophores brevibus, 8–10 x 2.5–3μ, confertis; conidiis hyalinis, flexuosis, filiformibus, ca. 60–90 x 1.5–2μ, continuis.

Leaf spots sordid gray-brown, angled, 2–3 mm. diam., often confluent, acervuli epiphyllous, scattered to gregarious, approx. 40–70μ diam.; conidiophores short, 8–10 x 2.5–3μ, crowded; conidia hyaline, flexuous, filiform, approx. 60–90 x 1.5–2μ, continuous.

On living leaves of *Vaccinium canadense.* Parfrey's Glen, Town of Merrimac, Sauk County, Wisconsin, U. S. A., August 24, 1956.

This seems a distinctive fungus and not one of the confusing assemblage of *Ramularias* that have been reported on *Vaccinium.* The spores sometimes appear faintly multiseptate, but are probably all continuous. They are often tapered toward the apex. The conidiophores are mostly crowded and compacted, but where observed free tend to be flask-shaped. I have found no reports of *Cylindrosporium* on any Ericaceae.

HAPLOBASIDIUM THALICTRI Erikss. on *Thalictrum revolutum.* Manitowoc Co., Two Rivers, July 12. Det. by S. J. Hughes. This corresponds closely with Sydow's Mycotheca germanica No. 847. Apparently the first report of occurrence in North America.

RAMULARIA CIRSII Allesch. on *Cirsium arvense.* Dane Co., Madison, August 25. This fungus was originally described on *Cirsium vulgare (lanceolatum)* and a variety *Cirsii-arvensis* C. Massal. was later set aside. The differences between species and variety, as described, would seem to fall within the range of what might be expected in a specific entity and to scarcely warrant recognition.

FUSICLADIUM SALICIPERDUM (All. & Tub.) Lind. on *Salix adenophylla.* Manitowoc Co., Point Beach State Forest near Two Rivers, July 12. An interesting specimen, in which the distinctive conidia correspond identically with those of Sydow's Mycotheca germanica No. 2796, issued as this species.

CERCOSPORA BRASSICICOLA P. Henn. on *Brassica arvensis.* Dane Co., Madison, August 16. The spores correspond to the figure and description in Chupp's "Monograph of Cercospora", but the phores seem more like those shown in some allied species, such as *C. armoraciae* Sacc. and *C. barbareae* (Sacc.) Chupp. It would seem that we have here an intergrading series.

CERCOSPORA TENUIS Peck on *Galium trifidum*. Racine Co., Racine, June 24, 1887, August 31, 1890, and Kenosha Co., July 10, 1898. All collected by J. J. Davis and originally labeled *Cercospora punctoidea* Ell. & Holw., later filed under *Cercospora galii* Ell. & Holw., on the assumption that *C. punctoidea* is a synonym of the latter. Chupp in his monograph states that this is incorrect and that *C. punctoidea* is actually a synonym of *C. tenuis,* not hitherto reported by that name from Wisconsin.

CERCOSPORA EUPATORII Peck on *Eupatorium altissimum*. Dane Co., Madison, August 31. According to Chupp, this species is alone among those known on *Eupatorium* in having well-defined spots. The conidia are unusual in being tapered to an awl-like tip.

Cercospora oligoneuronis sp. nov.

Maculis obscuro-flavidis, immarginatis, angulosis, parvis, 1–3 mm. longis, fasciis 4–8 cauliculis divergentibus, hypophyllis; conidiophoris septatis aliquoties, tortuosis, geniculatis aliquoties, fuscis, apicibus pallidioribus, 80–115 x 4–5.5μ; conidiis angusto-obclavatis, rectis vel curvis leniter, pallido-flavidis, 3–4-septatis, 45–60 x 2.5–3.5μ.

Spots dull yellowish, immarginate, angled, small, 1–3 mm. long; conidiophores 4–8 in fascicle, widely divergent and spreading, hypophyllous; several-septate, tortuous, several-geniculate, dark brown, somewhat paler at tip, 80–115 x 4–5.5μ; conidia narrowly obclavate, straight or slightly curved, pale yellowish, 3–4-septate, 45–60 x 2.5–3.5μ.

On living leaves of *Solidago riddellii.* University of Wisconsin Arboretum, Madison, Dane County, Wisconsin, U. S. A., August 17, 1956.

A very inconspicuous fungus. The spots are delimited by the anastomosing lesser veins and, along the margins particularly, are sometimes confluent to produce a rather elongate lesion. The specific name is derived from the generic appellation sometimes given the corymbose Solidagos.

THE LIVELIHOODS IN 1880 AND IN 1956 IN THE TOWN OF LIBERTY GROVE, DOOR COUNTY, WISCONSIN

OTTO L. KOWALKE
University of Wisconsin

The Town of Liberty Grove is the north end of the mainland of the Door County Peninsula that lies between Green Bay and Lake Michigan; and it is the largest town in that county. Door County was authorized by the Legislature in 1851; and the Town of Liberty Grove, the sixth town, was set off in 1859. The name, "Liberty Grove", was proposed by C. T. Morbeck who was clerk, assessor, treasurer, and justice of peace. (1)

The Liberty Grove area, in 1800, was completely covered with trees. The prominent species were maple, beech, ash, pine, hemlock, cedar (arbor vitae), spruce, tamarack, and balsam fir. Martin (1) quotes an early writer that "for the largest variety of timber and shrubs, our evergreen and forest tree dealers have scattered broadcast the fact that no section of America is equal to this peninsula."

Settlers came as early as 1836 to fish from Rock Island at the north end of the peninsula. There was a merchant at Ellison Bay by 1855 and one at Sister Bay in 1856 (1), so there must have been enough people in the area to support them. According to the U.S. Census of 1880, there were 1,092 persons in Liberty Grove. In 1876 a saw mill was built at Rowley Bay and another at Sister Bay which was still operating in 1956 (2). A third mill, built later, stood at the foot of the bluff in Section 15 just west of Ellison Bay.

The "farmer-lumberman" cut saw logs, cordwood, railroad ties, telegraph poles, fence posts, and made maple syrup and sugar. Hay was always a good crop; and wheat and oats brought better prices than in other parts of the State. For all those commodities there was a ready market (2).

Prices for forest products were low in 1880 when compared with those of 1956. For example, maple firewood was $2.12 a cord; cedar railroad ties brought 15 cents each; cedar poles 25 feet long sold for 37 cents each; and hemlock bark for tanning could be had for $3.00 a cord (2). The peeled hemlock logs were left in the woods to rot.

When the land had been cleared, it was planted to crops for man and farm animals. For man there were potatoes, wheat, rye, and vegetables. The cow or two, horses, pigs, and chickens lived on oats, millet, hay, and pasture. Corn was not raised because the growing season was too short for the seed then available. In 1956, corn was grown on many farms and the ears were large. Prior to 1910, farming yielded a modest income. It was not until cherry and apple culture and dairying were practiced, that farm incomes were raised.

Fishing was another means for livelihood. Besides the numerous commercial fishermen, there were also farmers, living adjacent to the shores, who fished for herring with "pound nets" in early spring and late autumn. In the early days the fish were largely salted and packed in wooden kegs for shipment, but some were also smoked. Fishing was once a lucrative occupation. But, the lamprey eel had, by 1956, killed most of the lake trout and made inroads on the white fish. In spite of the loss of the trout, commercial fishermen are still working at Sister Bay, Ellison Bay, and particularly at Gills Rock.

The routes to markets for farm, forest, and fish products in the early days, were Green Bay and Lake Michigan. By 1880, there were 13 piers along the shore line in Liberty Grove from which shallow draft schooners could take on cargo. One pier at Sister Bay and one at Ellison Bay were alongside water deep enough to serve fairly large steamers (2). The pier with its warehouse at Ellison Bay was owned by John Eliason and in 1915 it was known as the "potato dock". When boats, driven by gasoline engines, came to this region, they took dressed fish, packed in ice, to Sturgeon Bay or to Green Bay. In 1956, products like dressed fish, fresh fruits, and vegetables went by auto-truck to Milwaukee and Chicago, usually a night run.

Fruit-growing in Door County is said to have begun in 1862 when Joseph Zettle planted some apple trees just north of Sturgeon Bay. By 1892 he had 45 acres in apple orchard and harvested 3,000 bushels, and he exhibited some of them at the state fair. The exhibit came to attention of Professor Emmett S. Goff of the University of Wisconsin and Mr. A. L. Hatch, a fruit grower at Richland Center, Wis. Those men visited Door County in 1893 and they were so impressed by the possibilities that they bought 40 acres of land and planted some European and Japanese plums. They also planted a nursery containing 50,000 apple grafts and some cherries. Their venture was a success. By 1910, there were 185 acres in cherries in Door County and by 1923 there were 777 acres (3).

Apple and cherry growing in Door County is aided by the cold waters of Green Bay and Lake Michigan that give the peninsula a cool, backward spring. The blossom buds, being sensitive to frost, are retarded and often several weeks elapse from the time they first swell until they are in full bloom. By that time the dangers of frosts are over (3).

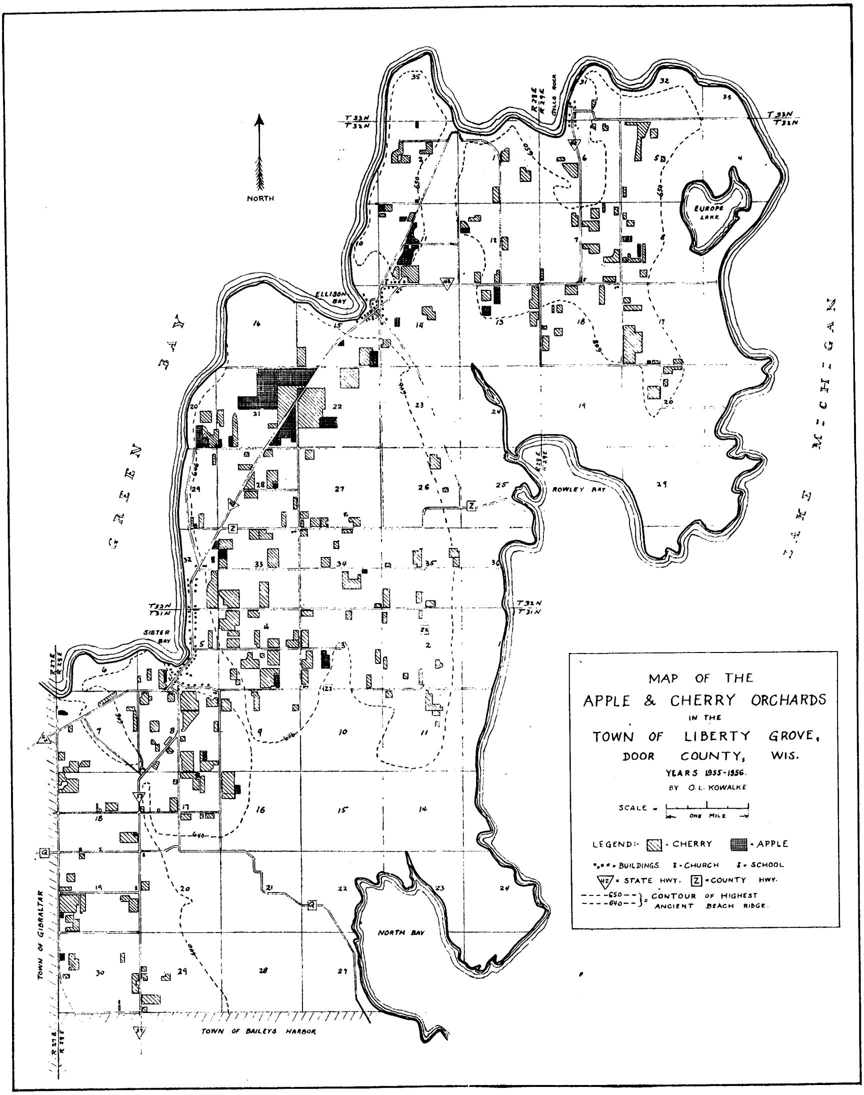
MAP OF THE
APPLE & CHERRY ORCHARDS
IN THE
TOWN OF LIBERTY GROVE,
DOOR COUNTY, WIS.
YEARS 1955-1956.
BY O.L. KOWALKE
SCALE =
ONE MILE
LEGEND:- = CHERRY = APPLE
= BUILDINGS. = CHURCH = SCHOOL
42 = STATE HWY. Z = COUNTY HWY.
650
640
= CONTOUR OF HIGHEST ANCIENT BEACH RIDGE.
NORTH
GREEN BAY
LAKE MICHIGAN
ELLISON BAY
ROWLEY BAY
SISTER BAY
NORTH BAY
EUROPE LAKE
GILLS ROCK
TOWN OF GIBRALTAR
TOWN OF BAILEYS HARBOR
T 33 N
T 32 N
T 31 N
R 28 E
R 29 E
R 27 E

PLATE 1.

The extent and location of the apple and cherry orchards in Liberty Grove are shown on Plate 1. The author with an assistant, in the summers of 1955 and 1956, paced off each orchard and located it with reference to the property boundary. The measurement by pacing is probably within two per cent correct and it is adequate for the purpose of this report.

It may be of interest to point out that practically all those plots of apples and cherries lie within the dashed lines that mark the contours of the beach ridges made by the ancient Lake Algonquin, following the last glacial period (4). The contours of the ridges lie at 640 to 650 feet above sea level and about 60 to 70 feet above the water of Lake Michigan. The orchards are thus exposed to air currents flowing across the peninsula and are thereby protected from frosts.

There are 32 plots in apples with a total area of 432 acres; and 205 plots in cherries with a total area of 2,088 acres. Of the cherry area, about 12 per cent is new planting not yet in bearing.

Most of the plots are tended by the owners who live on the land and such plots range in size from about one-half acre to about 40 acres. There is a large company-owned orchard along Highway 42, between Sister Bay and Ellison Bay in Sections 21 and 22, where there are 238 acres in apples and 224 acres in cherries. Another orchard company, in the last two years, has planted about 100 acres to cherries on land lying to the east of Ellison Bay. The greatest aggregates of owner-operated cherry orchards are immediately to the east and to the south of Sister Bay Village in Sections 4 and 8 where the total acreages are 167 and 156, respectively.

Picking cherries, up to about 1925, was done largely by the owner and his family and such local help as he could get. In 1956, most of the picking was done by migrant laborers from the South and Indians from Wisconsin.

Canning of cherries is done in several plants in Sturgeon Bay and also in the Growers' Co-operative Cannery about one and one-half miles east of Sister Bay on County Highway ZZ in the northwest corner of Section 10.

Dairying has developed considerably in Liberty Grove in the last 20 years. Whereas, in 1880, the farmer kept a few cows to supply his needs for milk, butter, and meat, he soon increased his herd when he could raise the food for them and sell the surplus milk. Small cheese factories in Liberty Grove bought the surplus milk and as late as about 1925 there were six such factories. Now there is none. In 1955, the number of milk cows in Liberty Grove was 970 and they produced an estimated seven and one-third million pounds of milk per year (5). When the highways were improved and the auto-truck came into use, it was feasible to haul milk longer distances. A milk condensery was built in 1917 at Sturgeon Bay by the Van Camp Company. That plant was sold to the Evangeline Milk Co. in 1944. The milk from the farms is collected daily in cooled cans and hauled by trucks with cooled transport housings to Sturgeon Bay. There appear to be no bulk storage and cooled tank trucks operating in Liberty Grove such as one sees in Southern Wisconsin.

In 1880, wheat was the principal crop and wheat production came to a peak about 1900. Now, in 1956, hay and alfalfa and oats are the principal crops. In 1951, nearly two-thirds of the cropland was in tame hay, one-fifth was in oats, about one-tenth in corn, and only about three per cent in wheat. The present crops are grown to feed cows for milk and beef and to feed hogs and chickens also grown for meat (3).

Other means for livelihoods now are the services and supplies to the summer visitors who either stay in the summer hotels or in cottages which they own or may rent. The first summer hotel, "Liberty Park", was built in 1900 by Abraham Carlson (2), near Sister Bay Village, one-half mile north of the Town Hall on Highway 42. By 1915 there were a number of private summer cottages in that neighborhood. Many summer cottages also were built along the shore at Ellison Bay, Garrett Bay, and Gills Rock. The shore line in Liberty Grove along Green Bay is about 17 miles long and about 65 per cent of the shore is now occupied by summer cottages and hotels. The shore on the Lake Michigan side, on the other hand, is about 33 miles long; and only about 15 per cent of it is used for summer cottages.

The summer cottages, moreover, are a good tax base. In the Town of Liberty Grove, excluding Sister Bay Village, the total "residential" assessment for 1955 was four per cent larger than the total "agricultural" assessment which included all the land and buildings on the farms and orchards. The "residential" assessments for the settlements at Ellison Bay and Gills Rock are a modest fraction of the total for the area under discussion. On that basis, it is estimated that the summer cottage assessments are about equal to the assessments on farms and orchards together with their improvements. In Sister Bay Village, the total assessed valuations of summer cottages and hotels are about equal to the total for the farms and orchards within the Village limits. Furthermore, the total assessed valuation of "residential" property in Liberty Grove is about equal to that for Sister Bay Village. The "agricultural" assessments in those two taxation units are also about equal (6).

Practically all the summer cottages and hotels use electricity and they were an important inducement to bring that service from Sturgeon Bay into the area. Electricity came to the farms also. Of the 141 farms in Liberty Grove reported to be operating in 1955, only five were without electric service (7).

The summer cottages and hotels have promoted the growth of business at Sister Bay which was incorporated as a Village in 1912. The permanent population in the Town of Liberty Grove has increased about 22 per cent from 1,092 in 1880 to 1,332 in 1950 (3). The Village of Sister Bay is the chief merchandising center for a large area. There, one can now do banking, buy household furnishings and utensils, get clothing for men, women, and children, obtain prescription and proprietary drugs, buy fresh bakery goods and groceries, have automobiles repaired and serviced, and secure numerous trades services.

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PRINTING AND JOURNALISM IN THE NOVELS OF WILLIAM DEAN HOWELLS

B. A. SOKOLOFF
University of Wisconsin Department of English

In the beginning was the printing-office. At the age of nine, in Hamilton, Ohio, William Dean Howells began to set type. According to his father's Swedenborgian philosophy, the boy was fulfilling a use. And for the boy, this was his introduction to words. Seventy-four years later, the old man was through with words, after being "a literary movement in himself." But at first there was type-setting, versifying, sketch writing, reporting and editing, and short story writing. All of these activities went into Howells' theory and practice of the novel, as he has told us and as later scholars and investigators have observed. The travel sketches blossomed into the earliest novels; the transition is almost imperceptible. In 1846 we find "The Old Man," as Howells was called by the other printers because of his gravity of manner, at his case.

> But as for the printer's craft with me, it was simply my joy and pride from the first thing I knew of it. I know when I could not read, for I recall supplying the text from my imagination for the pictures I found in books, but I do not know when I could not set type. My first attempt at literature was not written, but put up in type, and printed off by me.[1]

Howells may here be referring to "The Independent Candidate," a story which had a disastrous ending for Howells.[2] At the outset we have the image of a boy absorbed in attempts at writing and the work of printing so that printing and creative literature merge with such thoroughness that we cannot distinguish them separately. Neither could Howells, of course, Soon he could set type very well, and from ten years on "journalism became my university and the printing-office was my school."[3] The work became irksome to him as work becomes to any boy, but it never ceased to have charm for a man who never got the printer's ink out of his system. Although his interest in literature ran very high (literature was always his "passion") from a very early age, he was devoted to printing and journalism with a high sense of dedication. He always had a feeling of duty toward his work that gave him a living, and

[1] *Years of My Youth* (New York, 1916), 17.
[2] I shall discuss this story in greater detail in a later passage of this essay.
[3] *Years of My Youth*, 18.

in "The Man of Letters as a Man of Business" he announced that the creative writer, the artist, should look upon himself as a skilled worker similar to a craftsman in the manual trades. Howells never forgot that he entered letters through the aristocrat of trades, printing. Although his day was taken up with labor in the printing shop, and he had to make time for his studies, in the early days, at least in Jefferson, he did not begrudge the hours spent at the case.

In Hamilton the boy's day in the printing-office began at seven and ended at six. In Dayton, in 1849–50, Howells' day began at four or five and did not end until eleven o'clock when he helped put the telegraphic despatches into type. In the early dawn he delivered the papers. Later, in Jefferson, his working day was over at two because of his speed and skill. Any time not spent in working at the case in these early years was snatched for literature. "As soon as supper was over in the evening I got out my manuscripts, which I kept in great disorder . . . and sawed and filed, and hammered away at my blessed Popean heroics until nine, when I went regularly to bed, to rise again at five."[4] After the year in the log cabin at Xenia Howells went to Columbus with his father, who became clerk of the House of the Ohio Legislature. This was the boy's introduction to politics in the Ohio capital; he was to return in 1857 to become an editor and political journalist. But in 1851, at fourteen, Howells became a compositor on the *Ohio State Journal,* the paper he was to rejoin six years later. "In this way I came into living contact with literature again, and the day-dreams began once more over the familiar cases of type. A definite literary ambition grew up in me, and in the long reveries of the afternoon, when I was distributing my case, I fashioned a future of overpowering magnificence and undying celebrity."[5] This dream came true, at least partially.

The high point of Howells' career as journalist-printer came when Howells started work on the *Atlantic Monthly* on March 1, 1866. He was proof reader, editor, correspondent, and writer. Howells was made aware that the experience he had "as practical printer for the work was most valued, if not the most valued, and that as a proof reader he was expected to make it avail on the side of economy."[6] In exactly the same way Bartley Hubbard got his position on the Equity *Free Press.* "He apprenticed himself to the printer of his village, and rapidly picked up a knowledge of the business. . . . But it was as a practical printer, through the freemasonry of the craft, that Bartley heard of the wish of the Equity

[4] *Ibid.,* 44.
[5] *Ibid.,* 36.
[6] *Life in Letters of William Dean Howells,* Mildred Howells, ed., two volumes (Garden City, New York, 1928), I, 105, cited by Clara and Rudolph Kirk, *William Dean Howells* (New York, 1950), lxii.

committee to place the *Free Press* in new hands, and he had to be grateful to his trade for a primary consideration from them which his collegiate honors would not have won him."[7] Howells' publications in the *Atlantic*, Boston *Advertiser*, the New York *World*, and in Ohio periodicals corresponded to Hubbard's collegiate career. The lack of "the stamp of the schools" did not count against Howells. When Howells in a letter to Brander Matthews, July 22, 1911, identified himself with Hubbard (". . . yesterday I read a great part of *A Modern Instance*, and perceived that I had drawn Bartley Hubbard, the false scoundrel, from myself"), he might have been thinking of their common journalistic beginnings. Or perhaps he was exorcising the scoundrel of "the Agnes Repplier in pantaloons," a label fastened on Howells by H. L. Mencken.

The period from 1857 to 1861 saw Howells deeply absorbed in poetry; he was reading Tennyson and Heine, the latter of whom became his great "passion." He was soon writing Heinesque verses, imitations so close to the original that Lowell had to hold some of his contributions to the *Atlantic* to make sure that they were not by the German. Later Lowell told Howells to sweat the Heine out of his system. Steeped as he was in poetry, captured by the vision of Howells the Poet, he still held journalism very dear. He felt "pride and joy" when he began the work; at the *Ohio State Journal* in those years when the Civil War was about to crash down, "I could find time for poetry only in my brief noonings, and at night after the last proofs had gone to the composing-room, or I had come home from the theater or from an evening party, but the long day was a long delight to me over my desk in the room next my senior."[8]

Howells always remembered journalism before the Pinneys, Hubbards, and Bittridges dragged the calling down with their cheapness and sensationalism. He thought of it as closely allied to the literary life, and always he bore in mind the high literary and ethical quality of his family's newspaper, the Ashtabula *Sentinel*. The author who approached literature through journalism was as fine a literary man as the writer who came directly to it.[9] Gradually, as Howells' literary aspirations grew in intensity in the late fifties, he came to think of journalism as a stepping stone to the writer's life. He tried to make literature out of his journalism. And here we have the genesis of all his later work. The humor and irony of his comedies of manners are found early in his newspaper columns such as "News and Humors of the Mail" that he wrote for the *Ohio State Journal*. Here was not straight reporting but selec-

[7] *A Modern Instance* (New York, 1934), 31.
[8] *Years of My Youth*, 152.
[9] "The Man of Letters as a Man of Business," in *Literature and Life* (New York, 1902), 22.

tion passed through the prism of the Howellsian personality. "I tried to make my newspaper work literary, to give it form and distinction, and it seems to me that I did not always try in vain, but I had also the instinct of actuality, of trying to make my poetry speak for its time and place."[10] "The instinct of actuality." Here we have the germ of Howells' theory of realism; his practice of realism, too, began in his *Sentinel* and *State Journal* days.[11]

In *A Modern Instance* the newspaperman's club in its vibrant atmosphere of good fellowship reproduced the feelings that young Howells had about his craft. "None, indeed, who have ever known it, can wholly forget the generous rage with which journalism inspires its followers. To each of these young men, beginning the strangely fascinating life as reporters and correspondents, his paper was as dear as his king once was to a French noble. . . ."[12] The camaraderie of newspapermen was really of secondary importance to Howells, although he made significant friendships as a news writer and editor, not the least of which was his relationship with Governor Salmon P. Chase. But for Howells' art the most important role he assumed as a journalist was that of observer. It is quite true that he did not early or late come to close grips with all facets of life, but he was a spectator of life, even if only through the newspaper exchanges. Also, in his quiet way he was encountering large segments of life. William Lyon Phelps grasped the importance of this phase of Howells' career when he wrote:

> While [Henry] James was "studying," Howells was reporting for a newspaper, and a reporter of life he was to the end. I cannot help thinking that the journalistic work on that Ohio newspaper affected the novelist's art in no small degree. It made him observant rather than introspective, a chronicler rather than an analyser of life. He never lost zest for minute observation; nothing characteristically human seemed dull or unimportant. His eye was microscopic, and when he turned it on what some call commonplace events or commonplace people, they swarmed with exciting activities, as any tiny bit of life does under a microscope.[13]

To qualify and clarify Phelps' statement, one should note that Howells was not really a reporter in the sense of the man who deals directly with death, vice, calamity, and the other ills of mankind; in fact, he turned down a position with the Cincinnati *Gazette* which paid a very handsome salary, because he could not front life directly. But the important fact here is that Howells took on the role of the peripheral intelligence that observes and then narrates.

[10] *Years of My Youth*, 178.
[11] I shall treat this highly important subject in a later section of this essay.
[12] *A Modern Instance*, 196–97.
[13] *Howells, James, Bryant, and Other Essays* (New York, 1924), 172–73.

This role of spectator was in harmony with his sensitive and genteel character; he preferred the "cleanly respectabilities" and on the fringe of action he could avoid direct contact with the sordid happenings of everyday life.

II

Howells initially took on the role of spectator on the staff of the family newspaper, the Ashtabula *Sentinel,* half-owned by his father in 1852 and later owned for many years[14] by his brother Joseph. "From his fifteenth year to his twentieth he worked on it as a compositor and occasional contributor. . . . The impetus to write and study literature was quickened there daily as he heard the printers recite and pun and argue. The taste which appropriated writings from other unprotected publications informed and molded his style, providing models for him to imitate or shun."[15] In the *Sentinel* appeared the first story that is identified as Howells'; this is "The Independent Candidate." Like other sketches and studies and poems, he put this into type without first writing it. This practice combined with serial publication made for disaster. "Once, also, I attempted a serial romance which, after a succession of several numbers, faltered and at last would not go on. I have told in another place how I had to force it to a close without mercy for the heroine, hurried to an untimely death as the only means of getting her out of the way, and I will not repeat the miserable details here."[16] Howells' first story, printed when he was seventeen, is important because it shows us, for all its weaknesses, that the youth could write. Unending practice had produced a smooth style whose major fault was a tendency toward fine writing. But "he had a good sense of form in the short sketch, the single incident, but lacked powers of larger comprehensiveness and continuity."[17] He introduced too many characters and situations and could not bring the story to a successful conclusion. It is significant to note that this lack of control is also one of the chief shortcomings of his near-masterpiece, *A Hazard of New Fortunes,* published forty-six years later. The action of the early story, centered in a political campaign, is illustrative of his high interest in politics at the time. It also shows the influence of Dickens.[18]

The *Sentinel* was literary in tone and featured the writings of the leading contemporary English and American authors such as Poe, Hawthorne, Dickens, and Thackeray. This material was given

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[14] Joseph Howells was connected with the *Sentinel* for fifty-seven years.

[15] E. H. Cady, "William Dean Howells and the Ashtabula *Sentinel,*" *Ohio State Archaeological and Historical Quarterly,* LIII (January–March, 1944), 39.

[16] *Years of My Youth,* 96–7.

[17] Howells is the author of any bibliographical item for which an author is not given. Cady, 47.

[18] For a résumé of the story, see 44–5 of the above article.

a prominent place in the paper. Along with the best stories appeared coincidence-laden romances which relied on sentimentality and smug morality for their effect.[19] Howells' taste, fed on the best of the eighteenth and nineteenth centuries, was sure enough to reject the shoddy. It was probably these saccharine offerings which turned him against what he later called "romanticistic" fiction, fiction which dealt in falsehood and presented a lying picture of life, past or present. From 1886 on he led the battle against this lying fiction and for realism; from the "Editor's Study" in *Harper's* he fulminated against the F. Marion Crawford type of thing.

Before his first novel (*Their Wedding Journey,* 1871), "the thirty-four year old ex-printer and reporter, by this time editor of the *Atlantic,* had also written nearly eight hundred poems, editorials, reviews, short stories, travel sketches, and columns of social comment for Ohio, Boston, and New York periodicals. . . ."[20] In this welter of writings lay many ideas and situations which were to go into his early novels, especially the first three. In July of 1860 Howells went on a sight-seeing trip to Canada and New England. In "Glimpses of Summer Travel" for the Cincinnati *Gazette* and "En Passant" for the *Ohio State Journal* he reported his journey to Erie, Buffalo, Niagara Falls, Toronto, Montreal, Quebec, Portland, and Haverhill, Howells has the Marches go on a very similar trip in *Their Wedding Journey.*[21] The structure of this book and *A Chance Acquaintance* is based on a similar trip that Howells and his wife took in 1870. Howells' early writing, especially about courtship and marriage, reappears in altered form in the novels. " 'Fast and Firm, a Romance at Marseilles,' revolves around the typically Howellsian situation of a young man and woman, who have become acquainted by accident in Italy, being mistaken for husband and wife. Since this short story reached only the readers of the Ashtabula *Sentinel* in 1866, Howells placed Kitty Ellison and Arbuton of *A Chance Acquaintance* in the same situation seven years later."[22]

Typical of Howells' early journalistic writings was a column he had in the *Ohio State Journal,* called "News and Humors of the Mail." The characteristics he displayed in those columns of social comment remained with him for the rest of his life. From the exchange newspapers he collected items that would lend themselves to his twenty-year-old wit. "I called my column or two 'News and Humors of the Mail,' and I tried to give it an effect of originality

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[19] *Ibid.,* 41.

[20] William M. Gibson, "Materials and Form in Howells' First Novels," *American Literature,* XIX (May, 1947), 158.

[21] *Ibid.,* 162–63.

[22] *Ibid.,* 161.

by recasting many of the facts, or, when I could not find a pretext for this, by offering the selected passages with applausive or derisive comment."[23] Henry Bird, Hubbard's assistant on the Equity *Free Press,* wrote the same kind of column.[24]

One item[25] belies the idea of Howells' almost innate prudishness; it is probably not typical of the youth he was, but it is noteworthy for its irony: "Virtue must and shall be preserved—Three virtuous matrons of South Bend, Ind., tarred and feathered a woman of impure reputation, in the public streets of South Bend, a few days since. The citizens of South Bend looked on, but are 'excited.' " A literary comment demonstrates his humorous mild sarcasm: "Mrs. L. H. Sigourney of Hartford, Conn., furnishes fifty poor families in Boston with turkeys or fowls and pumpkin pies, of the best quality, too, for a Thanksgiving dinner. A deed so noble, that we can easily forgive her all the verses she has ever written."[26]

Of course, Howells' selection of items is very revealing of his state of mind. The following piece of news and its editorial treatment illustrates the young journalist's humanity:

> Thanksgiving day was observed in New York city by the usual sermons at the churches, at the Five Points Missions, and the other benevolent institutions. Business was generally suspended, and one man was murdered. An infamous and cruel hoax was played off on the poor by some soulless and brainless scoundrel, who announced through the *Herald* that food would be dispensed *gratis* at certain points. Thousands of starving wretches assembled to be disappointed.[27]

His anti-slavery views found expression in many selections such as the following: "A correspondent of the London *Times,* in a letter from St. Vincents, Cape Verd Islands, announces the arrival there of the U. S. frigate Niagara, having on board the Africans rescued by the Dolphin from the slave brig Echo. Four hundred and fifty slaves left Africa, of whom but two hundred and fourteen remain."[28] A man by the name of Hugh Hazlitt was sentenced in Maryland to forty-five years in jail for enticing slaves to run away. Here is Howells' comment: "A most just judgment! In this country one may massacre abolitionists in Kansas, one may pistol Irishmen —but to tell negroes of liberty, and counsel them to run away from their beloved Massas, is monstrous! Hazlitt escapes too easily with his forty-five years' imprisonment. He should have been burnt alive."[29] "Firing the Southern heart" was one of the pastimes of

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[23] *Years of My Youth,* 146.
[24] *A Modern Instance,* 71.
[25] *Ohio State Journal,* XXIII (January 26, 1860), 2.
[26] *Ibid.,* XXII (November 29, 1858), 2.
[27] *Ibid.,* (November 22, 1858), 2.
[28] *Ibid.,* (November 24, 1858), 2.
[29] *Ibid.,* (November 23, 1858), 2.

Howells and his fellow journalists of Northern sympathies on the *Ohio State Journal:* "A duel was fought last week on Staten Island, by two medical students from the chivalric state of North Carolina. After firing four times at each other with the most wretched success, they shook hands and made friends. It was about a lady, of course."[30]

It is impossible to say when Howells first thought of himself as a realist, but in his earliest writings, including his journalism, realistic tendencies are seen. So in an early sketch we find a note on the truthful treatment of material: "The reader will observe that I am making this account as dull and egotistical as possible, in order to give myself the air of a real traveler. It does not matter so much how far you go, and what happens, as how you tell the story of it. If you bully people with a long account of nothing, they will be very apt to think you a wonderful fellow of vast experience."[31] This sounds very much like part of his critical canon set forth in *Criticism and Fiction* and the edicts on realism that he handed down from the "Editor's Study" and "Editor's Easy Chair."

His political writing in the 1850's helps show his grasp of reality; it also points up the fact that for a great part of his career, Howells was actively engaged in political journalism. This period extended to his ten years with the *Atlantic*, first as assistant editor and then as editor. Professor Louis Budd in his article, "Howells' Blistering and Cauterizing," emphasizes the vehement quality of Howells' political writing on the *Ohio State Journal.*[32] Howells was so outspoken and caustic in expounding his views that a State Senator arose on the floor of the Ohio Legislature to object to the young man's virulence. Howells' rough methods apparently were standard for that time when all men took their politics very seriously. "But if the young editor in his 'blistering and cauterizing' was far from New Testament tactics, he was much at home in antebellum journalism."[33] Howells' freesoil and antislavery views, along with the rest of his political credo, placed him in the ranks of the Republican party when that group was formed. Howells, during his *Atlantic* years, "aided the Republican party from Boston just as he had done from Columbus and New York, . . . he made the *Atlantic* reflect political views acceptable to himself and most educated Republicans, and he in the main allowed his magazine to voice the conservative rationale."[34] These were still the years when Howells could make polite statements about Hay's *The Breadwin-*

[30] *Ibid.*, (November 25, 1858), 2.
[31] "I Visit Camp Harrison," *Ohio State Journal,* XXIII (August 31, 1859), 2.
[32] *Ohio State Archaeological and Historical Quarterly,* LXII (October, 1953), 334–47.
[33] *Ibid.*, 347.
[34] Louis J. Budd, "Howells, the *Atlantic Monthly,* and Republicanism," *American Literature,* XXIV (May, 1952), 155.

ners and Aldrich's *Stillwater Tragedy*. And he was still thinking of the American businessman as Silas Lapham; the novels from *Annie Kilburn* to *A Traveler from Altruria* were yet to come. The point I wish to make in this section is that the Ohio years of journalism were full of writings by Howells on political and economic issues, and that this preoccupation with the betterment of man's social lot was to find expression in his later work. As one might expect, much of Howells' fiction utilizes themes abstracted from this extremely important experience in his life.

III

The novels that have most to do with printing and printers and journalism and journalists are *The Story of a Play, A Modern Instance, Letters Home, The Quality of Mercy,* and *The World of Chance*. The world of printing and journalism is part of the background of other books such as *Indian Summer* and *The Kentons*. Again and again we find fragments of Howells in such men as Brice Maxwell, Bartley Hubbard, Colville, Ardith, and Shelley Ray. They are journalistic literary men out of the West, all provincials seeking to arrive in the city. All of Howells' journalistic threads are woven out of himself; he was the prototype for later times of the country boy of little formal education who leaped from the printer's case and small town paper to literary fortune in the great metropolitan center. Basil March, who followed Howells from Boston to New York, is another of his autobiographical types who is a journalist with strong leaning toward higher things in writing. In Indianapolis, March had translated from German in the newspaper exchanges when he thought himself "in Arkadien geboren."[35]

Colville, the middle-aged lover of *Indian Summer*, is a retired newspaper editor-publisher from Des Vaches, Indiana. Brice Maxwell looks very much like the young Howells in a sketch that Godolphin makes of him in *The Story of a Play*: ". . . [He was] young, slight in figure, with a refined and delicate face, bearing the stamp of intellectual force; a journalist from the time he left school, and one of the best exponents of the formative influences of the press in the training of its votaries."[36]

In 1857 Howells was writing a daily letter from Columbus for the Cincinnati *Gazette*, dealing with legislative proceedings in the capital. The letters which found favor with the editors were the reason he was offered the position of city editor with the *Gazette*, a position he declined because of his "morbid nerves." In 1860 he was writing letters from Columbus for the New York *World*. Almost all of his fictional journalists write letters such as Howells

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[35] *Their Wedding Journey* (Boston, 1872), 111.
[36] *The Story of a Play* (New York, 1898), 117.

wrote; they usually write a New York letter to Midland or Wottoma, Iowa, or even to Boston. They also write other kinds of material, forms that Howells knew.

> He [Bartley Hubbard] wrote long, bragging letters about Equity, in a tone bordering on burlesque, and he had a department in his paper where he printed humorous squibs of his own and of other people; these were sometimes copied, and in the daily papers of the State he had been mentioned as "the funny man of the Equity *Free Press*." He also sent letters to one of the Boston journals, which he reproduced in his own sheet, and which gave him an importance that the best endeavor as a country editor would never have won him with the villagers.[37]

While waiting for success as a playwright, Maxwell writes letters from New York for his old newspaper, the Boston *Abstract*. It was for the *Abstract* that he had written his sociological article on the significance of Northwick's defalcation in *The Quality of Mercy*. Like Howells, Maxwell "preferred to make his letter a lively comment on events rather than a report of them."[38] Ardith of *Letters Home*, who is going to write the epic of New York (something Howells approached in *A Hazard of New Fortunes*), debates writing a New York letter for the *Day* people of Wottoma, Iowa. He decides he would refuse even decent pay for it because he is going to devote himself to pure literature.

The problems of turning experience into literature and of escaping hack-work for literature occupied Howells' mind early and late and found their way into his novels. Like Howells in real life, his characters are always realizing material for creative writing even as an action unfolds. When Maxwell's wife faints and he thinks she is dead, Howells writes, "With a strange aesthetic vigilance he took note of his sensations for use in revising Haxard."[39] Ardith in *Letters Home* is asked by old Casman of the *Signal* to do a series on "The Impressions of a Provincial," giving an account of New York from a fresh country arrival's point of view.[40] When Ardith takes out Essie Baysley, a pure country type from his hometown in Iowa, he thinks: "I don't exactly see how the experience will work into 'The Impressions of a Provincial,' unless as an episode

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[37] *A Modern Instance,* 34.

[38] *The Story of a Play,* 196.

[39] *Ibid.,* 209.

[40] "The Impressions of a Provincial,"—this might almost be the title of Howells' five foot shelf. Perennially he was taken by the theme of the literary youth from the hinterland arriving in the big city with a manuscript in his handbag. Was Howells rewriting his autobiography, seeking to discover something of himself in the process? The above was suggested to me by a statement Lionel Trilling makes in his "William Dean Howells and the Roots of Modern Taste," *Partisan Review,* XVIII (September–October, 1951), 516–36.

of Bohemia or something of that sort, but it is pure literature. . . ."[41]

In the late nineties Howells told Theodore Dreiser in an interview how hack-work in his early years had kept him from writing. Although he loved printing and journalism, his highest ideal was pure literature, at first poetry, which obviously enough, was always his most undistinguished production. So Maxwell tells his mother: "Yes, I've got to get on in his [Pinney's] way while I'm trying to get on in my own. I've got to work eight hours at reporting for the privilege of working two at literature.[42] That's how the world is built. The first thing is to earn your bread."[43] His wife tells him in *The Story of a Play* that he has always said that there is nothing so killing to creative work as any kind of journalism.[44] She makes this statement when the matter of writing a New York letter comes up.

Shelley Ray has a large part of Howells in him; he sounds much like the Ohio poet of 1860 who had been printed by Lowell in the leading literary magazine of America, issued from sacrosanct Boston:

> He [Ray] had often been sensible himself of a sort of incongruity in using up in ephemeral paragraphs, and even leading articles, the mind-stuff of a man who had published poems in the *Century* Bric-a-brac and *Harper's* Drawer, and had for several years had a story accepted by the *Atlantic,* though not yet printed. With the manuscript of the novel he was carrying to New York, and the four or five hundred dollars he had saved from his salary, he felt that he need not undertake newspaper work at once again. He meant to make a thorough failure of literature first. There would be time enough to fall back upon journalism, as he could always do.[45]

Ford, free lance writer, of *The Undiscovered Country,* is another of Howells' would-be literary men. He writes potboilers and apparently is ashamed of the fact. There is no doubt that among Howells' hundreds of pieces of writing, especially after his 1885 contract with Harper and Brothers, there are many deliberate potboilers. In the following quotation there is a strong possibility that we hear Howells' own voice: "I am sorry to say that my work is mostly for the pay that it brings. I'm hoping to be something in another way by and by. In the meantime I write and sell my work. It's what they call potboiling."[46] The preceding statement occurs in a conversa-

[41] *Letters Home* (New York, 1903), 113.
[42] These are almost the exact words he used to Dreiser.
[43] *The Quality of Mercy* (New York, 1892), 114.
[44] P. 162.
[45] *The World of Chance* (New York, 1893), 3.
[46] *The Undiscovered Country* (New York, 1890), 299.

tion about the Shakers' paper. Ford maintained that the Shakers wrote out of pleasure and duty. In 1880, the year of publication of *The Undiscovered Country,* Howells was sure of a market for anything he wrote, and he was well on his way to the ten thousand dollar a year income he was to enjoy from about the middle eighties to his death. I imagine he must have winced more than once, recalling such gems as *A Fearful Responsibility* and *The Coast of Bohemia.*

In 1858 Howells attended a convention of Ohio newspapermen at Tiffin and wrote a poem celebrating the occasion. It extolled the journalist and breathed high hopes for the future of the profession. Late in the century he was to see the rise of yellow journalism, a painful sight for the ex-reporter-editor. Gone was the connection with literature; the "scoop" was the thing. Newspapers dealt in debased coin. How many of them, toward the end of the century, could say what Howells did of the Ashtabula *Sentinel:* "Upon the whole, our paper was an attempt at conscientious and self-respecting journalism; it addressed itself seriously to the minds of its readers; it sought to form their tastes and opinions . . . and I am sure that no one got harm from a sincerity of conviction that devoted itself to the highest interests of the reader, that appealed to nothing base, and flattered nothing foolish in him."[47] The conversations on the ethics of journalism are not extraneous material in *A Modern Instance* and *The Quality of Mercy.* Bartley Hubbard and Witherby share a view of journalism that Howells despised. When Hubbard is offered a position on the *Events,* he is quick to voice an agreement with Witherby that is not feigned. They agree that a newspaper's first duty is to make money. Howells in real life lamented the triumph of the business office of the paper over the editorial room. Hubbard in a conversation with Ricker states his idea of how to run a successful newspaper: "I should cater to the lowest class first, and as long as I was poor I would have the fullest and best reports of every local accident and crime; that would take *all* the rabble. Then, as I could afford it, I'd rise a little, and give first-class non-partisan reports of local political affairs; that would fetch the next largest class. . . ."[48] Later Hubbard would include news, gossip, and scandal about religion. Last would come fashion and society news.

Ricker represents Howells' point of view; in *A Modern Instance* he first aids Hubbard in his Boston career but soon grows disgusted with him when he observes at close range his utter lack of principle. Ricker says: ". . . I consider a newspaper a public enterprise, with certain distinct duties to the public. It's sacredly bound not

[47] *Years of My Youth,* 87.
[48] *A Modern Instance,* 297.

to do anything to deprave or debauch its readers; and it's sacredly bound not to mislead or betray them, not merely as to questions of morals and politics, but as to questions of what we may lump as advertising."[49] Hubbard's idea of the newspaper is underscored dramatically in the tavern where he gets drunk; when the Colonel is asked what he is presenting in his variety show, he replies: "Legs, principally. That's what the public wants. I give the public what it wants. I don't pretend to be better than the public. Nor any worse."[50] Howells spoils the effect at this point by having Hubbard repeat, "It's just so with the newspapers, too. . . . Some newspapers used to stand out against publishing murders, and personal gossip, and divorce trials. There ain't a newspaper that pretends to keep anyways up with the times, now, that don't do it! The public wants spice, and they will have it!"[51] Death comes to Hubbard in White Sepulchre, Arizona, when an irate "leading citizen" kills him because of comments Hubbard printed in his "spicy" paper.

The new race of newspapermen had in Howells' eyes lost its conscience. The Pinneys and Hubbards were unfortunately typical of a large number of the practising newspaper writers.

> It was notable that Howells' blackguards were often newspapermen, like Bittridge, in *The Kentons,* and Bartley Hubbard, who broke his [Howells'] law of mutual trust with their prying disregard of human dignity and rights. Like Henry James and Henry Adams, he detested these glib young journalists who represented the new publicity. As an old newspaperman, he disliked to see this new type pushing aside the journalists with a feeling for letters.[52]

Squire Gaylord, who had stamped Hubbard as irresponsible and egocentric from the first, at one point in *A Modern Instance* comments, "I don't know as I ever heard that a great deal of morality was required by a newspaper editor."[53] Although numerous critics have remarked that Hubbard's fall is not inevitable from the evidence of him that Howells presents, we see, in small ways, his gradual decline that is born of his essentially weak character. By no means can we say that the fate of Hubbard is a tragic one. Ben Halleck characterizes Hubbard well: "He was a poor, cheap sort of a creature. Deplorably smart, and regrettably handsome. . . . A fellow with no more moral nature than a baseball bat. The sort of chap you'd expect to find, the next time you met him, in Congress or the house of correction."[54]

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[49] *Ibid.*
[50] *Ibid.*, 302.
[51] *Ibid.*, 303.
[52] Van Wyck Brooks, *New England: Indian Summer, 1865–1915* (New York, 1940), 221–22.
[53] P. 23.
[54] *Ibid.*, 243.

Hubbard prints Kinney's account of the logging camps without the latter's permission and lets him think that Ricker had done the article. Bartley is flippant about violating confidences. "She [Miss Kingsbury] was a fresh subject, and she told me everything. Of course I printed it all. She was awfully shocked,—or pretended to be,—and wrote me a very O-dear-how-could-you note about it."[55] While interviewing Silas Lapham for the "Solid Men of Boston" series, Hubbard mocks the simple virtues of Lapham's early background. "Bartley could not deny himself this gibe; but he trusted to Lapham's unliterary habit of mind for his security in making it, and most other people would consider it sincere reporter's rhetoric."[56]

Lorenzo Pinney, seen at his "best" in *The Quality of Mercy,* is another example of the new journalist whom Howells abhorred. Pinney tells Maxwell: "You ought to go back on a salary, you'll ruin yourself trying to fill space if you stick on trifles."[57] Maxwell replies: "Such as going and asking a man's family whether they think he was burned up in a railroad accident, and trying to make copy out of their emotions? Thank you, I prefer ruin. If that's your scoop, you're welcome to it."[58] To Louise Hillary, Pinney stands for all that is terrible in journalism.

Of course, men like Hubbard and Pinney could not have succeeded, even temporarily, had not the newspapers they worked for encouraged their cheap and vulgar writing. Bartley had no trouble at all in selling his sketch on housing in Boston to the *Chronicle-Abstract.* Also, whenever possible, distortion and sensationalizing of news were considered standard practice by many newspapers.[59] On the other hand, Ricker toned down Maxwell's treatment of the Northwick case because Maxwell had placed a large burden of guilt on the society that produced such a phenomenon.

Looking back over this essay, we may begin to realize the high importance of the role of his printing and journalism experience in Howells' life and work. Perhaps the greatest significance of this experience was the contribution it made to Howells' theory of critical realism—the truthful treatment of the materials of life.

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[55] *Ibid.,* 227.
[56] *Ibid.,* 4.
[57] *The Quality of Mercy,* 102.
[58] *Ibid.,* 102–03.
[59] For several newspaper treatments of Northwick's embezzlement, see 132, 133–36 of *The Quality of Mercy.*

"THE RIME OF THE ANCIENT MARINER" AS STYLIZED EPIC

KARL KROEBER
University of Wisconsin Department of English

The many scholars and critics who have so variously interpreted "The Rime of the Ancient Mariner" agree at least that Coleridge has charged his simple ballad form with a strange but uniquely evocative verbal magic and has transformed the superficial sensationalism of the "Gothic" ballad into an impressive if elusive coherence. In this paper I wish to suggest that much of "The Ancient Mariner's" verbal witchery and "archetypal" significance arises from qualities of the poem which are closely analogous to those of the "quest" epic, and that these qualities are what distinguish "The Ancient Mariner" from poems of comparable length and with similarly "magical" subjects. In "The Ancient Mariner" the essence of one kind of epic is given compact expression through symbolic narrative.

In theme, surely, "The Ancient Mariner" is epical. However we interpret the poem, we must recognize that it deals with fundamental problems of good and evil, with near-universal human experience. Robert Penn Warren, for example, in his thoroughgoing interpretation of "The Ancient Mariner" finds two central and interlocked themes: that of establishing the "sacramental vision" of the universe as "One Life," and that of dramatizing the nature of the creative imagination.[1] Maud Bodkin regards the poem as an artistic embodiment of the archetypal experience of "rebirth," a psychic event that is so common that its results "are inherited in the structure of the brain."[2] Solomon Gingerich finds the poem to be an argument for the acceptance of a "necessitarian" view of the universe,[3] and C. M. Bowra believes that "The Ancient Mariner" analyzes the essential nature and meaning of crime and punishment.[4]

At any rate, if the Mariner is not forced into the perception of a new vision of the universe, he at least returns from his sufferings,

[1] Robert Penn Warren, *The Rime of the Ancient Mariner with an Essay by Robert Penn Warren,* New York, 1946.

[2] Maud Bodkin, *Archetypal Patterns in Poetry,* London, 1934, pp. 26–88.

[3] Solomon Francis Gingerich, *Essays in the Romantic Poets,* New York, 1929, pp. 29–34.

[4] C. M. Bowra, "The Ancient Mariner," *The Romantic Imagination,* Cambridge, 1949, pp. 51–76. Of course the scholarly starting point for all discussions of "The Ancient Mariner" is still Lowes' *The Road to Xanadu.*

in the fashion of epic heroes, with a more profound and comprehensive understanding of the human situation than he had embarked with. Indeed, what primarily distinguishes "The Ancient Mariner" from the many ballads of the supernatural which might otherwise claim kinship to it is the exclusiveness of its concentration—despite the extent and vivacity of its "miraculous" elements —upon human action and human values. At stake always amidst a natural world animated by superhuman spiritual creatures is the Mariner's essential humanity, just as in *The Iliad* Homer's primary concern in a world of bestial carnage ruled by capricious gods is the humanity of Achilles.

More specifically, "The Ancient Mariner" is reminiscent of the "epic of quest," a sub-type for which G. R. Levy has provided a concise definition.

> Its heroes fight chiefly in solitude, against demons who oppose their progress, 'monsters of their spirit's making.' If they start their journey with companions, they lose them on the way . . . They always cross the sea and meet women on strange shores who enchant or prophesy . . . they navigate the waters of death to learn their destiny.[5]

The most familiar epic of this type is, of course, *The Odyssey,* and I want to point out some unremarked similarities between that poem and "The Ancient Mariner." In doing so, however, I will refer also to the less well known *Gilgamesh,* a Babylonian epic, probably composed about 2000 B. C.,[6] which is available to American readers in a lively and readable form thanks to the verse translation of William Ellery Leonard of the University of Wisconsin. *The Odyssey* is a highly sophisticated poem of complex and unusual origins with some ambiguous, or at least debatable, purposes,[7] and it does not so readily as the more primitive and uncomplicated *Gilgamesh* display the characteristics of the "quest" epic in their purest form. Furthermore, it is parallels and analogies I am suggesting, *not* influences, and Coleridge could not have known *Gilgamesh,* for it was not published in Europe until 1872.[8]

The first twenty lines of "The Ancient Mariner" serve as a kind of introduction to the story:

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[5] G. R. Levy, *The Sword from the Rock,* London, 1951, p. 120.

[6] Alexander Heidel, *The Gilgamesh Epic and Old Testament Parallels,* Chicago, Second Edition, 1949, pp. 14–16. Without doubt the most literate translation of *Gilgamesh* is Leonard's. But Leonard seldom goes beyond the Old Babylonian version, and therefore misses a good deal that is found in the Sumerian, Assyrian, Hittite, and Hurrian versions. Heidel's translation, though uninspired, is based on a collation of all available texts, so I use it and all references are to it.

[7] G. R. Levy, *op. cit.,* p. 144.

[8] Heidel, *op. cit.,* p. 2.

It is an ancient Mariner,
And he stoppeth one of three.
By thy long grey beard and glittering eye,
Now wherefore stopp'st thou me? . . .

He holds him with his glittering eye—
The Wedding-Guest stood still,
And listens like a three years' child:
The Mariner hath his will.[9]

Three interrelated characteristics of the Mariner are insisted upon in this introductory scene: his age (he has experienced much), his glittering eye (he has seen strange things), and the power of his will. Coleridge dramatizes those characteristics of the Mariner which the author of *Gilgamesh* describes at the opening of his epic as of central significance to his hero.

He who saw everything, of him learn, O my land;
He who knew all the lands, him will I praise . . .
He saw secret things and obtained knowledge of hidden things .
He went on a long journey and became weary and worn;
He engraved on a tablet of stone all the travail.[10]

Compare, too, the opening lines of *The Odyssey*.

> This is the story of a man, one who was never at a loss. He had travelled far in the world . . . he endured many troubles and hardships in the struggle to save his own life and to bring back his men safe to their homes. He did his best, but he could not save his companions. For they perished by their own madness, because they killed and ate the cattle of Hyperion the Sun-God, and the god took care that they should never see home again.[11]

We may note that one of Odysseus' most destructive antagonists is named at once as the god of the sun. Gilgamesh, too, has difficulties with a sun god,[12] and several critics have pointed out that the Mariner's disasters occur under the "aegis of the sun" and his beneficent experiences under the "aegis of the moon."[13] In other words, the primary symbolic structure of Coleridge's poem parallels a basic *motif* of the quest epic: the "night journey," restoration through descent into the realms of darkness.

We observe, also, that *The Odyssey's* introduction stresses the importance of returning home, returning to all the activities and

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9 S. T. Coleridge, *Complete Poetical Works*, ed. by E. H. Coleridge, London, 2 vol., I, p. 187, 11. 1–20.

10 Heidel, Tablet I, column i, p. 16.

11 Homer, *Odyssey*, translated by W. H. D. Rouse, London, 1937, p. 1.

12 Heidel, III, v, p. 38. For the beneficence of the moon see IX, i, p. 65. The clarity of this point is obscured by the overlapping functions of the gods Anu, Enlil, Ea, and Shamash. See VII, i, p. 56 and Heidel's note (113) on that page.

13 Kenneth Burke, *The Philosophy of Literary Form*, Baton Rouge, 1941, p. 24 ff.

satisfactions that "home" implies. The same stress is apparent in *Gilgamesh,* where, immediately succeeding the lines I have quoted, the reader is given a description of Uruk, the city from which Gilgamesh departs on his strange pilgrimage and to which, after his return "a sadder and a wiser man," he dedicates his life.

> He built the wall of Uruk, the enclosure
> Of holy Eanna, the sacred storehouse.
> Behold its outer wall, whose brightness is like that of copper!
> Yea, look upon its inner wall, which none can equal!
> Take hold of the threshold, which is from of old! . . .
> Climb upon the wall of Uruk and walk about;
> Inspect the foundation terrace and examine the brickwork.[14]

The wedding scene which opens and closes "The Ancient Mariner" is symbolically equivalent of Uruk and Ithaca. The Mariner does not disrupt this most primary of social and domestic festivities, but the shadow of his weird experience falls across its gaiety, just as the trials of Gilgamesh and Odysseus throw into a more profound perspective the middle-class solidity and comfort of Uruk and the bourgeois contentment of Odysseus' island palace.

Finally, observe that "The Mariner hath his will." Coleridge's ancient sailor does not, to be sure, have the *mēnis* of an Achilles, the violent wilfulness of Gilgamesh, but when he commands the Wedding-Guest to listen that "gallant" "cannot choose but hear." The Mariner wantonly shoots the albatross. When the spectre-ship appears he is the man who bites his arm and sucks his blood in order to cry out. When he falls into the Pilot's boat and the Pilot's boy "doth crazy go" the Mariner seizes the oars. Finally, his "O shrieve me, shrieve me, holy man!" to the tottering Hermit rings more of command than of prayer. This is not, certainly, the divinely wilful pride of Gilgamesh, who

> . . . leaves no son to his father, day and night his outrageousness
> continues unrestrained;
> And he is the shepherd of Uruk, the enclosure;
> He is their shepherd, and yet he oppresses them. . . .
> Gilgamesh leaves no virgin to her lover,
> The daughter of a warrior, the chosen of a noble.[15]

But the difference between Gilgamesh and the Mariner is one of degree, not of kind. It can be said of Coleridge's poem as truly as of *Gilgamesh* or the Homeric epics that

> The deepest significance of each of these archetypal masterpieces lies in the reduction of . . . pride by means of a bereavement which imposes the recognition of a common humanity.[16]

[14] Heidel, I, i, p. 17.
[15] Heidel, I, ii, p. 18.
[16] Levy, *op. cit.,* p. 124.

The Mariner's ship, driven by a storm, at first travels South to the lands of ice and snow and then sails North into the tropical Pacific.[17] The cause of this reversal is the Mariner's catastrophic act (which occurs just after he has won through terrible perils, as is the case with both Odysseus and Gilgamesh) of shooting the albatross, an act which parallels the slaying of the Sun-God's oxen in *The Odyssey* and the destruction of the Bull of Heaven in *Gilgamesh.* The shooting of the Albatross leads to the death of the Mariner's shipmates, even as the slaughter of the oxen entails the destruction of Odysseus' companions and the killing of the Bull of Heaven results in the loss of Gilgamesh's one comrade. After these critical acts all three heroes undergo a period of terrible isolation, an isolation especially poignant because filled with beauty, but an inhuman beauty. Gilgamesh finds his way into an Eden-like garden where

> The carnelian bears its fruit;
> Vines hang from it, good to look at.
> The lapis-lazuli bears foliage;
> Also fruit it bears, pleasant to behold.[18]

Odysseus, constrained by the love of the radiant Calypso, is offered the pleasures of her delightful island and the gift of eternal youth.

The Mariner, it is true, finds in the weird beauty of the water snakes the means to begin his resurrection. But, like Odysseus and Gilgamesh, he needs supernatural assistance to effect his release—"Sure my kind saint took pity on me." And, like the other two heroes, the Mariner's most desolate moment of isolation is that instant in which the remote, inscrutable loveliness of the night heavens sinks into his soul.

> In his loneliness and fixedness he yearneth towards the journeying Moon, and the stars that still sojurn, yet still move onward; and everywhere the blue sky belongs to them, and is their appointed rest and their native country and their own natural home, which they enter unannounced as lords that are certainly expected and yet there is silent joy at their arrival.[19]

Like Gilgamesh and Odysseus the Mariner is brought back to his native land in a tranced condition and by a vessel supernaturally propelled. The importance of sleep and of prophetic visions throughout "The Ancient Mariner" is paralleled by a similar emphasis in both of the earlier epics.[20] And when the Mariner

[17] It has not been remarked so far as I know how Coleridge dramatizes the change in the Mariner's situation from hunter to hunted by means of two "mirror" similies. Cf. 11. 45–50 and 11. 442–451.

[18] Heidel, IX, v, p. 68.

[19] Coleridge, *op. cit.,* gloss to 11. 263–271, p. 197.

[20] There is, indeed, a curious analogue in *Gilgamesh* to the two voices which the Mariner hears discussing his fate on his homeward voyage. When Gilgamesh, who must stay awake for six days to conquer death, falls asleep, Utnapishtim, the god

arrives safe if shaken at his home port, his ship sinks magically, even as the ship of Alcinous which carries Odysseus home is destroyed by Poseidon. And if the Mariner's return does not result in the terrific bloodshed caused by Odysseus' homecoming, its effect is far from pleasant. The hermit can scarcely stand, the Pilot falls in a fit, and the Pilot's boy "doth crazy go." And then, like *The Odyssey* and *Gilgamesh,* "The Ancient Mariner" concludes with a kind of epilogue which seems unnecessary and not in keeping with the tone of the rest of the poem.

> O sweeter than the marriage-feast,
> 'Tis sweeter far to me
> To walk together to the kirk
> With a goodly company!—
>
> To walk together to the kirk,
> And all together pray,
> While each to his great father bends,
> Old men and babes, and loving friends
> And youths and maidens gay. . . .
>
> He prayeth best, who loveth best
> All things both great and small;
> For the dear God who loveth us,
> He made and loveth all.[21]

It is primarily the stylistic flatness of these final verses, I believe, which has led many commentators to reject their explicit "moral" as an expression of the true inner meaning of "The Ancient Mariner."[22] Their weakness may, however, parallel the awkwardness of the notorious twenty-fourth book of *The Odyssey,* where, to quote one critic,

> there is an inevitable slackening of tension, discernible in the verse, because this . . . book entails a tying up of all remaining threads after the drama of the return has been accomplished.[23]

Even more illuminating, it seems to me, is the analogue of *Gilgamesh,* wherein the hero has explicitly rejected the temptation of a mere unthinking life of sensuous enjoyment (perhaps implied to the Mariner by the wedding-feast).

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who conducts the trial, remarks scornfully: "Look at the strong man who wants life everlasting." His wife, however, answers gently: "Touch him that the man may awake,/ That he may return in peace on the road by which he came." And later she persuades Utnapishtim to reveal a secret of the gods to the broken-hearted hero, because "Gilgamesh has come hither, he has become weary, he has exerted himself." In Coleridge's words: The other was a softer voice,/ As soft as honey-dew;/ Quoth he: the man hath penance done,/ And penance more will do.

[21] Coleridge, *op. cit.,* ll. 600–615, pp. 208–209.

[22] For discussions of this problem see Newton P. Stallknecht, "The Moral of the Ancient Mariner," *Publications of the Modern Language Association,* XLVII, 1932, pp. 559–569, and Elizabeth Nitchie, "The Moral of the Ancient Mariner Reconsidered," *PMLA,* XLVIII, 1933, pp. 867–878.

[23] Levy, *op. cit.,* p. 156.

Thou, O Gilgamesh, let thy belly be full;
Day and night be thou merry;
Make every day a day of rejoicing.
Day and night do thou dance and play.
Let thy raiment be clean,
Thy head be washed, and thyself bathed in water.
Cherish the little one holding thy hand,
And let thy wife rejoice in thy bosom.[24]

This divine advice Gilgamesh refuses. Although he ultimately comes to accept the limitations of human life and to value the simple material and social virtues of his city, he does not deceive himself as to the pain inherent in the human condition. Like the Mariner, whose "agony returns," Gilgamesh, after his difficult journey and painful return must descend to hell and learn for the benefit of his people the fate of his hard-won wisdom and humanity.

"Tell me, my friend; tell me, my friend;
Tell me the ways of the underworld which thou has seen."
"I will not tell thee, my friend; I will not tell thee.
But if I must tell thee the ways of the underworld which I have seen,
Sit down and weep."[25]

Compared to this saddest and bitterest of conclusions, Coleridge's

He went like one that hath been stunned,
And is of sense forlorn:
A sadder and a wiser man,
He rose the morrow morn.[26]

may seem trivial, but the purpose and meaning of the two epilogues are manifestly the same.

The parallels which I have suggested between "The Ancient Mariner" and *The Odyssey* and *Gilgamesh* are, I believe, valid, and more detailed analogies could be enumerated.[27] But is there any value in finding this kind of similarity? Do such parallelisms explain anything about "The Ancient Mariner?" If one reads Coleridge's poem as an epic of quest, condensed into symbolic form of course, one discovers the explanation for certain otherwise rather baffling qualities of "The Ancient Mariner."

For example, such a reading explains why the poem, so dangerously tinged by the artificial supernaturalism of the worst romantic horror-mongering, is charged with such coherent symbolic significance. According to this reading, the poem's language, metaphoric structure, and organization of incidents and scenic details are all determined by a unified total design which is epic, a design, that is,

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[24] Heidel, X, iii, p. 70.
[25] Heidel, XII, i, p. 99.
[26] Coleridge, *op. cit.*, ll. 621–625, p. 209.
[27] For example, the symbolic significance of forests and trees to each of these poems so profoundly concerned with the sea.

as profound, meaningful, and evocative as literature is capable of. Is not the "magic" of "The Ancient Mariner" the feelings we experience when we finish reading the poem, feelings different in degree from our response to other poems, lyric, elegiac, or purely narrative, of equal brevity and apparent simplicity?

Moreover, a reading of "The Ancient Mariner" as a stylized epic of quest illuminates the meaning and purpose of Coleridge's extensive revisions of the poem, particularly his addition of the prose gloss. In general, Coleridge in reworking the poem reduced rather than expanded.[28] As has been observed, he consistently modified or deleted the sensational features of his early version, *e.g.*, the arms of the seraphs burning like torches, toning down those elements most immediately reminiscent of the supernaturalism of the "horror" ballads.[29] The character of the Mariner Coleridge stylized, discarding his more "quaint" and ludicrous aspects.[30] He reduced to an essential minimum the purely balladic formulae which had predominated in the original poem. He tended to retain those formulae —phrases like, "To Mary Queen the praise be given," "mine own countree," repetitions like "Water, water, every where," and internal rhyme—which are not so specifically balladic as suggestive of the generic qualities of popular literature. All of Coleridge's revisions of the verse can be understood as efforts to emphasize the symbolic and universal aspect of his poem and to de-emphasize the peculiarities and idiosyncrasies inherent in his ballad original.

His one major addition, the prose gloss, not only provides an extra temporal dimension,[31] but also supplies a perspective of sophistication. It is an artistic device which serves to make the "primitiveness" of the verse immediately and vigorously available to the civilized reader. The naïveté, linguistic and intellectual of the "learned" prose commentator is about mid-way between the "barbaric" naïveté of the poem and the sophistication of the modern reader. The gloss functions as a medium of transmission.

But the gloss bears a more dynamic relation to the versification. It enriches the apparent simplicity of the brief verse narrative by making the totality of the poem a complex interplaying of prose and verse forces. The gloss, being prose, asserts rhythms, musical, emotional, dramatic, different from those of the verse. Sometimes the prose retards the movement of the poetry, thus emphasizing the continuity of symbolic elements.[32] Occasionally Coleridge uses the

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[28] The fullest discussion of Coleridge's emendations is to be found in the article of B. R. McElderry, Jr., "Coleridge's Revision of 'The Ancient Mariner,'" *Studies in Philology,* XXIX, 1932, pp. 68–96.

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

[30] Coleridge, *op. cit.,* p. 187, note.

[31] Huntington Brown, "The Gloss to 'The Rime of the Ancient Mariner,'" *Modern Language Quarterly,* VI, 1945, pp. 319–324.

[32] See 11. 103–106.

gloss to accelerate the pace of the verse, sometimes by foreshadowing.[33] And, though usually the gloss is more literal than the verse, at times the prose evokes a richer imaginative context than the poetry, as in the passage depicting the Mariner's yearning toward the moon. And all these complications of texture provide "The Ancient Mariner" with evocative overtones which cannot be created in lyrical or simple narrative poems but which are the essential and characteristic feature of epic poetry.[34]

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[33] Good examples are ll. 119–123 and 164–170.

[34] Neither Coleridge nor any of his contemporaries ever suggested that "The Ancient Mariner" was an epic. Could Coleridge have written a stylized epic without being conscious of doing so? Investigations of his attitude toward "popular" literature will show, I believe, that he could have, but limitations of space forbid a discussion of this important matter here.

HENRY AINSWORTH, A FOUNDING FATHER OF CONGREGATIONALISM AND PIONEER TRANSLATOR OF THE BIBLE

SAMUEL A. IVES
University of Wisconsin Memorial Library

The earliest recorded instance of independent English translation of any portion of the Bible after publication of the Authorised Version of 1611 comes from one of the ablest scholars among the seventeenth-century Nonconformists.[1] Henry Ainsworth was born of yeoman stock at Swanton Morley, Norfolk, in 1570.[2] After being for three years under the tutelage of a Mr. Clephamson, Ainsworth entered St. John's College, Cambridge, about 1586, and a year later transferred to Gonville and Caius College where he remained for four years, according to an entry in the admissions records of that institution.[3]

Ever since the early 1560's, following the Elizabethan Act of Uniformity, the Nonconformist or Independent Protestants had been increasingly active. To one such group, the Brownists, named for their leader, Robert Browne (1550–1633), Ainsworth attached himself. This group, the spiritual ancestors of the present-day Congregationalists, claiming autonomy for each particular church or congregation, resented any form of controlled religion, Presbyterian or Episcopalian, and desired only to be let alone—a condition of religious existence which was in Elizabethan England a virtual impossibility. Although Browne himself ultimately recanted and submitted to Episcopal discipline in 1585, his followers, regarding him as a renegade, continued to hold meetings in their conventicles both in England and later in Holland, whence they were finally forced to emigrate.[4]

It is in Amsterdam that Ainsworth next appears about 1593, where, to support himself, he is said to have taken service with a bookseller as a porter and, according to a statement of Roger Williams, "lived upon nine pence in the weeke, with roots boyled."[5]

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1 Hugh Pope, *English Versions of the Bible . . . Revised and amplified by Rev. Sebastian Bullough, O.P.* (St. Louis, 1952), p. 511.

2 *Dictionary of National Biography;* W.E.A. and Ernest Axon, *Henry Ainsworth, the puritan commentator* in *Transactions of the Lancashire and Cheshire Antiquarian Society,* vol. VI (1888), p. 42 ff.

3 J. and S. C. Venn, *Admissions to Gonville and Caius College.*

4 Cf. H. M. Dexter, *The Congregationalism of the last three hundred years, as seen in its literature . . .* (New York, 1880), p. 61 ff.

5 Dexter, *op. cit.,* p. 283 (note), quoting from: John Cotton, *A reply to Mr. Williams answer to Mr. Cottons letter* (London, 1647), p. 119.

Three years later Ainsworth's powers as preacher and teacher and especially his skill as a Hebraist resulted in his being chosen pastor of the Brownist congregation in Amsterdam who were awaiting the arrival from America of their proper minister, Francis Johnson (1562–1618). Johnson, after being exiled from England and vainly attempting to gain asylum in Newfoundland, finally joined his spiritual brethren in Amsterdam in 1597, where Ainsworth continued in the capacity of "teacher".

Ainsworth's labors with Johnson in organizing the group of dissenters was by no means easy. Already the renowned John Robinson, who preached the farewell sermon to those departing on the Mayflower, had left Leyden to escape the acrimonious bickerings and contentions of the Nonconformists and to join another small group headed by one John Smyth, known as the "Se-Baptist" from his having first baptized himself and afterwards his followers.[6] But in the city of Amsterdam, at that time a veritable melting-pot of Protestant dissent, the three hundred Brownists under Johnson and Ainsworth included many who were by no means a credit to the group: a riff-raff of religious and political malcontents who resented any domination whatever, spiritual or political, and who were often divided quite as much among themselves as in their professed enmity to the Church of England. Such a motley group proved ultimately an object of suspicion and disfavor to the civil authorities in Amsterdam, which fact but added to the burdens of their leaders.

Finally, to make matters even worse, came a split in the Brownist ranks themselves, brought on by a controversy between Ainsworth and Johnson as to the seat of authority, Johnson claiming that it rested with the leaders of the group, while Ainsworth contended that all ecclesiastical powers and specifically that of excommunication resided in the congregation itself, as in modern Congregational Christian churches. After vainly attempting to come to a reconciliation with Johnson, Ainsworth and his followers finally withdrew in December, 1610, largely, it would seem, on the basis of Ainsworth's interpretation of Christ's command as stated in *Matthew* XVIII.17. ("If he refuses to listen to them, tell it to the church; and if he refuses to listen even to the church, let him be to you as a Gentile and a tax collector.")[7]

The two groups thus formed came to be known, at least to their opponents, as Ainsworthian and Franciscan Brownists. One result of the split was a lawsuit for the possession of the conventicle itself, brought on, it would seem, by Johnson's followers, but ultimately decided in Ainsworth's favor, the Johnsonians eventually

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[6] Dexter, *op. cit.*, p. 319 and note, 324.
[7] *Ibid.*, p. 325 ff.

removing to Emden, while Ainsworth continued as pastor of his own group for twelve years more. His death is said to have occurred in 1622 or 1623.[8] There is apparently no picture of him extant, while his signature seems to have survived only in his marriage certificate.[9]

II

Most influential among Ainsworth's numerous theological writings was his *Annotations upon the five books of Moses, the Psalms and the Song of Songs,* a work which was originally issued in parts.[10] The first of these was entitled: *Annotations upon the first book of Moses called Genesis. Wherein the Hebrew words and sentences are compared with & explained by the ancient Greek and Chaldee versions: but chiefly by conference with the holy Scriptures.* This first appeared in the year 1616 and was reprinted in 1621. The same title, with slight variations, was used for his *Annotations* upon Exodus (1617), *Leviticus* (1618), *Numbers* (1619), *Deuteronomy* (1619) and *Psalms* (1612 and 1617). All these editions were printed in Amsterdam, though the title-pages indicate no place of printing, a fact apparently indicative of the type of "underground" publishing Ainsworth first employed to get his works circulated in England. In 1622 the first collected edition of the work appeared, wherein only *Genesis* and *Exodus* were included in new editions, the other three books being merely reprints. Finally in 1627 the works were again collected into a folio edition, printed in London by John Bellamie. It was in this volume that Ainsworth's annotations on the *Song of Songs* first appeared. This book was reprinted without textual alteration in London by M. Parsons for John Bellamie in 1639.[11]

Ainsworth's *Annotations* include complete independent translations of each of the books, together with extensive commentaries. The several chapters of each book are separately treated, though the text is not set off in verses, as in the 1611 Bible. Verse numeration is, however, indicated by marginal numbers. Each chapter is followed by the "Annotations" which are both critical and exegetical, and is prefaced by analytical summaries as in the Authorized Version, though usually more extensively. The *parashaim* or fifty-four "great sections" of the Torah are always indicated in the

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[8] For the curious legends regarding the manner of Ainsworth's death, cf. Dexter, *op. cit.*, p. 343 (note 199).

[9] Reproduced in Dexter, *op. cit.*, p. 296.

[10] Cf. appendix *infra, A brief listing of Ainsworth's works,* nos. 2–12.

[11] Axon (*op. cit.*, p. 49) erroneously mentions a first collected edition of 1619 and a subsequent one of 1621, the latter probably copied from the error in Watt's *Bibliotheca Britannica.* Cf. Dexter, *op. cit.*, p. 342 (note 191). The *Annotations* on *Psalms* was translated into German and those on the *Song of Songs* into both German and Dutch. Cf. Dexter, *ibid.*

notes by the familiar Hebrew letter Pe thrice repeated. Each of the books of the Pentateuch is preceded by a brief summary and list of chapters. In the 1627 and 1639 collected editions the "Table of some principall things observed" which follows the text and annotations includes at the end several lists of references of a purely grammatical nature, such as: "Overplus or redundance of words which in other languages may be omitted" and "Change or putting one word for another", though the actual cases of such recurrences in the text and notes would seem far to outnumber the few instances there cited.

Since publication of the *Annotations* in parts had apparently elicited a certain amount of criticism, justified or otherwise, the author appended to the 1627 collected edition "An advertisement to the reader, touching some objections made against the sincerity of the Hebrew text, and the allegation of the rabbins, in these former annotations." The greater portion of this essay, extending over more than six folio leaves, is concerned with the problem of the *k'thib* and *q'ere* readings, in an effort to vindicate the equally inspired nature of both. Herein Ainsworth goes to great lengths in citing the varieties of these types of readings and shows how they have been dealt with by the ancient and modern editors and translators of the Hebrew text. The sum-total of his defence for apparent eclecticism in their use appears to lie in the citation of authoritative precedent. The name of his critic or the work wherein he was censured is nowhere mentioned, but is probably that of an English churchman.

Probably the most original feature of Ainsworth's translation appears at *Exodus* XV where Moses' song of triumph is given in a metrical version of six-line stanzas, together with the music to accompany it. With the latter is the statement: "This may be sung to the 113. Psalme", which psalm, indeed, is found with the identical melody in many of the older editions of the metrical version. The poetical version of Moses' song is, however, offered as an alternate to Ainsworth's prose translation which is in a parallel column.

The same arrangement is found for Moses' song in *Deuteronomy* XXXII, though for the musical accompaniment no parallel is here cited.

More ambitious, though without the accompanying music, is Ainsworth's metrical translation of the *Song of Songs* with a parallel prose version. Though scarcely to be reckoned as inspired poetry rather than mechanical metre painfully beaten out and savouring throughout of the Puritanical psalms, this translation deserves notice as one of the earliest attempts at a metrical paraphrase of this book.

III

To gain an idea of Ainsworth's method and style, we may examine his *Annotations* on *Genesis* which is here described from a copy of the 1621 edition. The work is preceded by a preface of over six pages, entitled: *Concerning Moses writings and these annotations upon them.* Herein the patriarch is said to have been born about the year 2432 A.M. or 1496 B.C. After a brief survey of the life of Moses and the general significance of the five books of which he is stated to be the author, Ainsworth continues (*op. cit.*, fol. 2 verso): "The literall sense of Moses Hebrew (which is the tongue wherein he wrote the Law) is the ground of all interpretation; and that language hath figures and properties of speech different from ours: those therefore in the first place are to be opened, that the naturall meaning of the scripture being knowen, the mysteries of godlinesse therein implied may the better be discerned. This may be atteyned in great measure, by the scriptures themselves; which being compared, doe open one an other . . . ." This statement he follows by numerous illustrations of interpreting Scripture by Scripture, citing allegedly parallel passages which supplement and, in some measure, correct each other. Herein, in the course of showing uses of the plural for the singular, and vice versa, in the synoptic gospels, Ainsworth includes the famous Petrine commission (*Matthew* XVI. 17–19), comparing it with Christ's words as recorded in *John* XX. 22–23, "which some not observing would restreyn the keyes of the kingdome to Peter onely." Yet this is followed by a series of other passages wherein the commentator would restrict a statement to one individual or object only! Thus, after comparing *Deuteronomy* VI.13: "him shalt thou serve" with *Matthew* IV.10: "Him only shalt thou serve" and similar carefully chosen passages, Ainsworth makes bold to assert (*op. cit.*, fol. 3 verso): "Accordingly Paul sayth a man is not justified by the works of the law, *but by the faith of Iesus Christ,* Gal. 2.16. where by is meant, by faith onely." The two labored parallels above cited reveal something of Ainsworth's method of proving Scripture by Scripture to justify his own ideas, in much the same method as that employed by modern Biblical literalists, as contrasted with the historical and traditional approach on the one hand and liberal interpretation on the other.

Regarding his method of interpretation and translation, Ainsworth says (*op. cit.*, fol. 4 recto): "I have chiefly laboured in these annotations upon Moses to explain his words and speeches by conference with himself and other Prophets & Apostles, all of which are commenters upon his lawes . . . for by a true and sound literall explication the spirituall meaning may the better be discerned. And the exquisite scanning of words and phrases, which to some may seem needlesse, will be found (as painfull to the writer) profitable to the reader. Our Saviour hath confirmed the Law, unto every *jote* & *tittle* Matt. 5.18. that we should not think any word or sentence to bee used in vaine . . ."

Ainsworth then goes on to explain that he has compared the "Greeke & Chaldee" versions, interpreting by whichever has seemed to him to offer the best explanation of any particular passage. By the "Chaldee" the author apparently refers to the Targums, use of which, according to him, may serve a double purpose: to enlighten the reader on technical points of the law and to provide occasional places where the rabbis appear to contradict themselves, to the benefit of the Christian. Evidence from the Church Fathers and pagan authors, however, he thinks should be sparingly cited, the former because they are abundantly supplied in other commentaries, the latter because they are comparatively useless for the author's purpose.

Ainsworth concludes his lengthy preface with the modest statement: "But forasmuch as my portion is small, in the knowledge of holy things; let the godly reader try what I set down, and not accept it, because I say it: and let the learned be provoked unto more large and fruitfull labours in this kinde. The Lord open all our eyes, that we may see the marveilous things of his Law." Thus Ainsworth is seen to be not merely a Nonconformist, but quite a liberal as well, readily acknowledging the ability of each individual to interpret Scripture by his own light.

IV

Some idea of Ainsworth's individual translations may be gained from the following collation of the first chapter of *Genesis* in his version with the texts of the Authorized, Revised and Revised Standard versions. Other variant versions or interpretations cited by Ainsworth in his notes have been added in his own words, where his translation differs from all of the other three.

In making this collation the following abbreviations have been used:

A.V.—*The Holy Bible, an exact reprint, page for page, of the authorized version published in the year MDCXI.* Oxford: The University Press, by Samuel Collingwood & Co., 1833. 2 vols.

R.V.—*The Holy Bible containing the Old and New Testaments translated out of the original tongues: being the version set forth A.D. 1611 compared with the most ancient authorities and revised. Printed for the universities of Oxford and Cambridge.* Oxford: The University Press, 1885.

R.S.V.—*The Holy Bible. Revised standard version containing the Old and New Testaments translated from the original tongues. Being the version set forth A.D. 1611, revised A.D. 1881–1885 and A.D. 1901, compared with the most ancient authorities and revised A.D. 1952.* New York: Thomas Nelson & Sons, 1952.

Ainsw.—Ainsworth's annotations as given in the edition of 1627.

Genesis I.

1. Heavēs: Heauen, A.V., R.V.; heavens R.S.V., with the Hebrew.
2. emptie: without forme, A.V., R.S.V.; waste, R.V. Ainsw.: "Hebr. emptiness: a thing *emptie,* without inhabitants, & *void* without ornaments; a deformed wilderness, and a wast: and so unfit for use, not being separated from the waters, not having light, herbes, trees, beasts, birds, or people to adorn and inhabit it, Gen. 2.5. This sense the Chaldee paraphrase also yeeldeth; and the Prophet confirmeth it, saying, He created it not to be emptie [*in vaine,* A.V.; *a waste,* R.V.] he formed it to be inhabited. Esa. 45.18. and when extreme emptinesse and desolation of a place is meant, it is expressed by (*Tohu* & *Bohu*) the words here used. Esa. 34.11. Ier. 4.23. or by one of them, as Psal. 107.40. Deut. 32.10." The Hebrew *tohū* is used alone in *Isaiah* XLV.18.
4. separated betweene the light and the darknesse: diuided the light from the darknesse, A.V., R.V. [note to A.V.: Hebr. betweene the light and betweene the darknesse.]; separated the light from the darkness, R.S.V. Ainsw.: "*separated betweene.*] that is, divided the light from the darknesse . . . The Hebrew phrase is, he *separated betweene the light and betweene the darknesse.* So after usually."
5. the evening was, and the morning was [so in v. 8, &c.]: the euening and the morning were. [note: Hebr. and the evening was, and the morning was, &c.] A.V.; there was evening and there was morning, R.V., R.S.V.
6. Out-spred firmament [so in vv. 7, 8]: firmament [note: Hebr. Expansion] A.V.; R.V., R.S.V. Ainsw.: Outspred firmament.] This name is of the Hebrew *Rakiagh,* which signifieth *a thing spred abroad,* and of the Greek *stereoma* which signifieth *a firmament* or *fast thing* . . ." separate, betweene waters and waters [so in vv. 7, 14, &c.]: diuide the waters from the waters, A.V., R.V.; separate the waters from the waters, R.S.V. Ainsw.: "separate] or, *let it be separating,* that is, let it continually separate, or divide . . ."
8. Heavens: Heauen, A.V., R.V., R.S.V. Ainsw.: "Heavens] in Hebrew, *Shamajim:* so called, as is thought, of *Sham, There,* and *Majim, waters* which are removed, or heaved up from us. And so the whole, hath the name of a part thereof . . ."
11. bud-forth the budding-grasse: bring forth grasse [note: Heb. tender grasse] A.V.; put forth grass, R.V.; put forth vegetation, R.S.V. the herb seeding-seed: *and* herbe yeelding seed, A.V., R.V. [om. *and*] plants yielding seed, R.S.V. Ainsw.: "yeelding:] Hebr. *making,* that is, bearing and bringing forth . . ."
16. for the rule of the day [twice]: to rule [note: Hebr. *for the rule* of the day, &c.] AV., R.V., R.S.V.
16. also the starres: *he made* the starres also, A.V., R.V., R.S.V.
20. bring forth abundantly the moving-thing, the living soule: bring forth abundantly the mouing [note: or, *creeping*] creature that hath life [note: Heb. *soule*] A.V., R.V. [note: Heb. swarm with swarms of living creatures]; swarms of living creatures, R.S.V. Ainsw.: "*the moving thing:*] or, as the Greek translateth, *creeping things.* But the Hebrew, *Sherets,* is

more large than that which wee call the creeping thing, for it conteyneth, things moving swiftly in the waters, as swimming fishes, &c. . . ."
on the face of the outspred- firmament of the heavens: in the open [note: Heb. face of the firmament of heaven] firmament of heaven, A.V., R.V. [note: Heb. on the face of the expanse of the heaven]; across the firmament of the heavens, R.S.V.

21. every living creeping soule: every living creature that moueth, A.V., R.V., R.S.V. Ainsw.: "*creeping.*] The Hebrew *remes*, which hath the nature of *treading*, is also largely used, for things creeping on the earth, or swimming in the waters . . ."
24. the living soule: the living creature, A.V., R.V.; living creatures, R.S.V.
25. every creeping thing of the earth [so v. 30]: euerything that creepeth vpon the earth, A.V., R.V. [. . . upon the ground], R.S.V.
26. according to our likenesse: after our likenesse, A.V., R.V., R.S.V. heavens: aire, A.V., R.V., R.S.V.
27. in his image: in his owne image, A.V., R.V., R.S.V.
28. fill the earth: replenish the earth, A.V., R.V.; fill the earth, R.S.V. of the heavens [so v. 30]: of the aire, A.V., R.V., R.S.V. creepeth: moooueth [note: Heb. creepeth] A.V., R.V., R.S.V. [moves].
29. seeding seed: bearing seede [note: Hebr. seeding seed] A.V.; yielding seed, R.V., R.S.V.
30. which hath in it a living soule: wherein there is life [note: Hebr. a living soule] A.V., R.V.; that has the breath of life, R.S.V.

The above collation, though brief, is quite sufficient to show the tenor of Ainsworth's work. It would be interesting and instructive to pursue such a collation further, noting especially the instances where Ainsworth's translation is bourne out by the R.S.V. as against the A.V. and R.V., as shown above in several cases.

Although the translator has gone to great lengths to compare the readings of the Septuagint and Targums, probably deliberately omitting the Latin Vulgate as papish, the results seem hardly commensurate with the effort expended. As stated by J. Isaacs (*The Authorized Version and after* in *The Bible in its ancient and English Versions*, ed. H. W. Robinson. Oxford: Clarendon Press, 1940; p. 225 f.); "His faithful renderings . . . are not accompanied by felicity or music of style and retain an over strict Hebrew order contradicting the English idiom." Ainsworth's faults as a translator are probably largely to be attributed to his dominant Puritanical attitude which exalted the "letter" over the "spirit" and, in true rabbinical fashion, shrank from altering "one jot or tittle" of the inspired Word.

Yet, with all his shortcomings and inconsistencies, Henry Ainsworth emerges as a figure of whom present-day Congregationalists may justly be proud, both as a founding father of the free church and as a pioneer in independent English translation of the Bible. Indeed, his influence was long felt not only among the Pilgrim Fathers and their immediate descendents, but also among the Massachusetts Bay Puritans for nearly a century.

The Ainsworth Psalter,[12] first printed in 1612, remained in continuous use among the Saints and their descendents for eighty years, when, in 1692, it was officially replaced by the famous *Bay Psalm Book.*[13] How these rudely composed verses of Ainsworth's "metrical translations", examples of which we have already considered elsewhere, appealed to the seventeenth century Puritan intellect the modern student of literature can only imagine. In the well known verses from Longfellow's *Courtship of Miles Standish* John Alden comes upon Priscilla sitting at home:

> "Open wide on her lap lay the well-worn psalm-book of Ainsworth,
> "Printed at Amsterdam, the words and the music together,
> "Rough-hewn, angular notes, like stones in the wall of a churchyard,
> "Darkened and overhung by the running vine of the verses . . ."

Though apparently not destined to be one of the stalwart group aboard the *Mayflower,* Ainsworth was always revered as their most scholarly teacher and, as Moses to the Israelites, an inspiration to the Pilgrim Fathers in their quest for the promised land.

A Brief Listing of Ainsworth's Works, according to Pollard and Redgrave's *Short-Title Catalogue of English Books, 1475–1640* (London, 1946), with Locations of Copies as recorded in William W. Bishop's *A Checklist of "Short-Title Catalogue" Books* (Ann Arbor, 1950).

1. An animadversion to Mr. Clyfton's advertisement. 4o. Amsterdam: G. Thorp, 1613. L, C; CtY, DLC, MBC, MWA, NNC.
2. Annotations upon Genesis. 4o. [Amsterdam] 1616. L, C; CtHWatk, CtY, DFo, IU, NhD.
3. [Anr. ed.] 4o. [Amsterdam?] 1621. L, C; CSmH, CtY, DFo, MBC, MBrZ, NN, NNUT-Mc, SAI. [Variant with imprint: *Miles Flesher f. John Bellamie, 1626* in NNUT-Mc].
4. Annotations upon Exodus. 4o. [Amsterdam] 1617. L, O, C; CSmH, CtY, DFo, IU, MBC, MBrZ, NhD, SAI.
5. [Anr. ed.] 4o. J. Haviland f. J. Bellamie a. B. Fisher, 1622. L; NN, NNUT-Mc.
6. Annotations upon Leviticus. 4o. [Amsterdam] 1618. L, C; CSmH, CtHWatk, CtY, DFo, IU, MBC, MBrZ, NN, NNUT-Mc, SAI.
7. Annotations upon Numbers. 4o. [Amsterdam] 1619. L, C; CSmH, CtHWatk, CtY, DFo, IU, MB, MBC, MBrZ, MH, NN, NNUT-Mc, NjPT, SAI.
8. Annotations upon Deuteronomie. 4o. [n.p.] 1619. L C; CSmH, CtHWatk, CtY, DFo, IU, MB, MBC, MBrZ, MH, NN, NNUT-Mc, NjPT, SAI.

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[12] Cf. appendix *infra,* no. 12.

[13] Cf. G. F. Willison, *Saints and Strangers* (N. Y. [c1945], p. 481, n. 16. The *Bay Psalm Book,* though poetically hardly above Ainsworth's Psalter, might have suffered a similar obscurity had it not chanced to be the first book known to have been printed on the North American continent (Cambridge, Mass., 1640). The last known available copy was sold at auction in New York in 1947 at the record high price of $151,000! It is now in the Yale University Library.

9. Annotations upon the five bookes of Moses and the booke of Psalmes. 6 pts. 4o. J. Haviland f. B. Fisher, 1622. [Reissues of Genesis, 1621; Exodus, 1622; Leviticus, 1618; Numbers, 1619; Deuteronomy, 1619; Psalms, 2nd ed., 1617.] L; CtHWatk, DFo, DLC, ICU, MB, MBrZ [No general t.-p.; 5 pts. (omitting *Psalms*)], MH, NNUT-Mc.
10. [Anr. issue] J. Haviland f. J. Bellamie, 1622. C; DLC, MiU [pt. 4–6].
11. Annotations upon the five books of Moses, the book of Psalms and the Song of Songs. 7 pts. fol. M. Flesher f. J. Bellamie, 1627–26. [General title dated 1627, separate titles 1626, with name of printer and catchwords from book to book.] L, C, WN[2], DUR[1, 3]; CSmH, CtY, DFo, ICU, IU, MA, MB, MHi, NN, NNC, WU, SAI.
12. [Anr. ed.] fol. M. Parsons f. J. Bellamie, 1639. L, O, C; CtHWatk, CtY, DFo, ICN, ICU, IU, MH, MWA, MiU, NN, NNU-H, NNUT-Mc, NjP, SAI.
13. An arrow against idolatrie. Taken out of the quiver of the Lord of Hosts. [Initials: H. A.] 8o. [Amsterdam] 1611. L, D[2]; CSmH.
14. [Anr. ed.] 8o. [n.p.] 1624. L[3], C; DFo.
15. [Anr. ed.] 8o. [n.p.] 1640. L, C[3]; CtY, MB.
16. [Anr. ed.] 8o. Nova Belgia, 1640. L; CtY, MBC, MH, NHi, NN, NNUT-Mc.
17. Annotations upon the book of Psalms. Second edition. 4o. [n.p.] 1617. L, C; CSmH, CtHWatk, DFo, ICU, IU, MBC, MBrZ, MH, NN, NNUT-Mc, NRU, NjPT, TxU, SAI.
18. The book of Psalms, with annotations. Englished both in prose and metre, by H. A. Amsterdam, G. Thorp, 1612. L, D[2]; CtY, DFo, MB, MBC, MH, MWA. [Ed. of 1618: MH]
19. A censure upon a dialogue of the Anabaptists intituled, A description of what God hath predestined concerning man. 1623. COLG; CSmH, NNUT-Mc.
20. Certain notes of Mr. Henry Ainsworth, his last sermon. Taken by pen by one of his flock. 8o. [n.p.] 1630. O; CtY.
21. The communion of saincts. 8o. [Amsterdam, G. Thorp] 1607. L[2]; MB.
22. [Anr. ed.] Reprinted in the year 1615. 8o. [Amsterdam?] 1615. L, O, D[2]; CSmH, CtY, DLC.
23. [Anr. ed.] 8o. [Amsterdam?] 1618. L; MH.
24. [Anr. ed.] 8o. Reprinted. [n.p.] 1628. O, C; CtY, DFo, MB, MH.
25. [Anr. ed.] 8o. Amsterdam, 1640. O; CtY, DFo.
26. [Anr. ed.] 8o. Nova Belgia, 1640. L.
27. Counterpoyson. Considerations . . . Answered by H. A[insworth]. 4o. [Amsterdam?] 1608. L; CtY, DFo, DLC, MB.
28. A defence of holy scriptures, worship and ministrie against M. Smyth. 4o. Amsterdam: G. Thorp, 1609. L; CtY, MBAt, MWA.
29. A reply to a pretended Christian plea for the anti-christian church of Rome. 4o. [n.p.] 1620. L, C[3]; CtY, DFo, NNUT-Mc.
30. A true confession of the faith, which wee falsely called Brownists, doo hold. [Anon.] 4o. [Amsterdam?] 1596. L, O; CSmH, CtY, MBC.
31. Certayne questions concerning 1. Silk or wool in the high priests ephod between H. Broughton and H. Ainsworth. 4o. [Amsterdam?] 1605. [By Hugh Broughton] L, C[3]; CSmH, CtY, DFo, MH, NNUT-Mc.
32. An epistle sent unto two daughters of Warwick, with a refutation by H. A[insworth]. 4o. Amsterdam, 1608. [By H. Niclas] L, O, C; CSmH, CtY, NNUT-Mc.
33. The trying out of the truth in certayn letters between J. Aynsworth and H. Aynsworth. 4o. [n.p.] 1615. L, C; CtY, DFo, DLC, NNUT-Mc.

34. An apologie or defence of such true christians as are commonly called Brownists. [Anon.] 4o. [Amsterdam?] 1604. [By Henry Ainsworth and Francis Johnson] L, C; CtY, DFo, DLC, ICN, IU, MB, MBC, MH, MWA, NNUT-Mc, PPL.
35. [Anr. ed. Anon.] 4o. [Amsterdam?] 1604. [Sig.* iij,l.1: "the in".] L, C; CSmH, DFo, MH.

Key to Abbreviations of Locations

C—Cambridge University Library, Cambridge, England.
C^3—Emmanuel College Library, Cambridge University, Cambridge, England.
COLG—Colgate Library.
CSmH—Henry E. Huntington Library, San Marino, California.
CtY—Yale University Library, New Haven, Connecticut.
CtHWatk—Watkinson Library, Hartford, Connecticut.
D^2—Marsh Library, Dublin, Ireland.
DFo—Folger Shakespeare Library, Washington, D.C.
DLC—The Library of Congress, Washington, D.C.
DUR^1—Durham Cathedral Library, England.
DUR^3—Cosin Library, Durham, England.
ICN—Newberry Library, Chicago, Illinois.
ICU—University of Chicago Library, Chicago, Illinois.
IU—University of Illinois Library, Urbana, Illinois.
L—The British Museum Library, London, England.
L^2—Lambeth Palace Library, London, England.
L^3—Dr. William's Library, London, England.
MA—Amherst College Library, Amherst, Massachusetts.
MB—The Boston Public Library, Boston, Massachusetts.
MBAt—The Boston Athenaeum Library, Boston, Massachusetts.
MBC—The Congregational Library, Boston, Massachusetts.
MBrZ—The Zion Research Library, Brookline, Massachusetts.
MH—Harvard University Library, Cambridge, Massachusetts.
MHi—The Massachusetts Historical Society Library, Boston, Massachusetts.
MiU—University of Michigan Library, Ann Arbor, Michigan.
MWA—The American Antiquarian Society Library, Worcester, Massachusetts.
NhD—Dartmouth College Library, Hanover, New Hampshire.
NHi—Library of the New York Historical Society, New York, N.Y.
NjPT—Princeton Theological Seminary Library, Princeton, New Jersey.
NN—The New York Public Library, New York, N.Y.
NNC—Columbia University Library, New York, N.Y.
NNU-H—University Heights Library, New York University, New York.
NNUT-Mc—The McAlpin Collection, Union Theological Seminary Library, New York, N.Y.
NRU—University of Rochester Library, Rochester, N.Y.
O—The Bodleian Library, Oxford University, England.
PPL—The Library Company of Philadelphia Library, Philadelphia, Pennsylvania.
SAI—The private library of Samuel A. Ives, Madison, Wisconsin.
TxU—University of Texas Library, Austin, Texas.
WN^2—Winchester College Library.
WU—University of Wisconsin Library, Madison, Wisconsin.

Note.—Further material relating to Henry Ainsworth, his life, work and influence, may be found in the article on him in the *Dictionary of National Biography*, together with the works there cited, on which most of the facts in the first portion of this essay have been based.

"THE VISIONARY GLEAM" AND "SPOTS OF TIME"—A STUDY OF THE PSYCHOLOGY-PHILOSOPHY OF WILLIAM WORDSWORTH

RALPH ALAN MCCANSE
University of Wisconsin Extension Division

Two expressions peculiar to the terminology of William Wordsword afford light upon certain important concepts of this poet. He uses them in salient passages of his poems. Separately they have had considerable attention upon the part of critics concerned with his system of thought. But no comparative analysis of the two terms has ever been published, though such comparison of *the visionary gleam* and *spots of time* as Wordsworth uses these terms of his own coining in referring to his subjective experience—indeed to subjective human experience typically—reveals important general contrasts and, upon one essential condition, a still more significant identity.[1]

These unique phrases both apply to subjective experience. Both bear upon emotional life.[2] Both are so far involved in Wordsworth's psychological system that they may actually be viewed as quasi-technical in nature and may be so interpreted. Both have to do with what Wordsworth in *The Recluse* avows is his outstanding preoccupation: viz., "the Mind of Man"—and to a notable degree as he uses these terms he means elements and systematic processes in that mind physically. Positively or negatively these same terms are significant regarding aspects of growth of the human mind, as Wordsworth conceives of it—from the inception of consciousness (and even previously) through demonstrable stages of complexity to a maturity of reason and constructive imagination.[3]

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[1] The late Professor Arthur Beatty recognized the character and essential importamt of these phrases and recurred to them singly or together in his study "William Wordsworth, His Doctrine and Art in their Historical Relations," University of Wisconsin Studies in Language and Literature, Number 24, Madison, 1st Edition, 1922; 2d Edition, 1927. This work, which underlies much of the significant Wordsworth study of recent years, has an enduring value which renders somewhat inadequate the term "pioneering" which has been applied to it. My own analysis is indebted to it at every turn; at times, in the face of misleading criticism, I should have been "halted without an effort to break through," had it not been for the aid of Beatty's critique.

[2] *The Prelude* XII, lines 269–270.

[3] Aside from Beatty's work, perhaps the finest tribute to Wordsworth as a psychologist is to be found in the article by M. Leguois constituting Chapter V, Volume XI, of the *Cambridge History of English Literature.* "Poetical psychology is his triumph," declares this critic of Wordsworth; and he calls attention to the passage (in the note to "The Thorn") where poetry is described as a "history or science of feeling."

By these two phrases, "the visionary gleam" and "spots of time," Wordsworth refers to subjective phenomena in ways that have important bearing upon what he means by *Imagination* and by *Intuition* (erroneously held by some commentators to be identical in Wordsworth's terminology).[4] And finally there is involved also the controversial questions of mysticism, so-called in this poet.

The visionary gleam and spots of time can indeed be defined from the standpoint of factual brain physiology as well as, less tangibly, in the field of abstract psychology. This is not to pervert or force and distort the poetry where the terms find mention, but is in the purest spirit of their author's purpose. It is directly conducive to a richer appreciation of the poetry.

The *visionary gleam* finds most familiar exposition in the "Ode: Intimations of Immortality from Recollections of Early Childhood." *Spots of time* are defined most explicitly in *The Prelude,* Book XII, lines 207 ff. These and relevant passages elsewhere will be cited in detail in the present study as it proceeds to analysis and comparison.

The *visionary gleam* is "fugitive".[5] Except under special conditions of recollection which we shall note in Wordsworth's references later, it is confined to the periods of childhood and youth.

> "There was a time when meadow, grove, and stream
> The earth, and every common sight,
> To me did seem
> Apparelled in celestial light,
> The glory and the freshness of a dream . . ."

> "The Youth . . . still . . . by the vision splendid
> Is on his way attended . . ."

But, Wordsworth declares in his maturity, "The things which I have seen I now can see no more." "The radiance which was once so bright," he asserts, is "now forever taken from my sight."

"Whither is fled the visionary gleam," he asks. "Where is it now, the glory and the dream?" "Nothing," he laments, "can bring back the hour of splendor . . . Of glory . . ."[6]

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[4] Legouis, op. cit., page 104, perhaps fosters this widespread erroneous view. Yet he declares that Wordsworth never consented to a "divorce between imagination and reality." The significance of this declaration lies in an inherent and yet frequently unrecognized difference between intuitive immediacy and a mental process Wordsworth calls Imagination. The latter process, according to Wordsworth, invariably acts over established and physiological **media** or neural paths in the brain. This factual, physical, realistic concept will be explained below.

[5] "Ode: Intimations," line 136.

[6] Ibid., lines 56–57. This is not to say that the youthful visionary experience of the vision is irrecoverable. It is important, as we shall see, in Wordsworth's system to note that this vision may be recalled, as in "The Cuckoo". But its validity is a *recollected* thing, dependent on the Mind of Man, where it is stored away. The "hour" of the gleam is in the past; it is a glory whose immediacy is vanished.

By way of contrast, *spots of time,* moments of keen awareness of life, are "scattered everywhere, taking their date from our first childhood."[7]

But they are distinctly valid in maturity: "The days gone by return upon me," declares Wordsworth in *The Prelude.* In our minds are "rememberable things"[9] that are stored away cortically, physically, in what the poet calls "the hiding places of man's power"; and he refers in *The Waggoner* to subjective "hiding places ten years deep" that "leap" at certain times into consciousness.[10] These are "visitings of imaginative power" recalled from the past;[11] by them "our minds are nourished and invisibly repaired"; they arise from

> "those passages of life that give
> Profoundest knowledge to what point, and how,
> The mind is lord and master—outward sense
> The obedient servant of her will."

Such spots of time "retain a renovating virtue"; from them, Wordsworth insists, he has subsequently been enabled in spirit to drink "oft" —and "as at a fountain". That spots of time, therefore, are not "the gleam, the light that never was, on sea or land" is expressly evident because in "Elegiac Stanzas Suggested by a Picture of Peele Castle" Wordsworth repudiates the visionary "gleam" as a "fond illusion . . . which nothing can restore," whereas he values these hiding places, these "spots of time," these "visitings of imaginative power,"[12] and hopes while he is in his prime to enshrine them in his verse and give lasting "substance and life" to them for the sake of his future and more decrepit years—years in which mentality begins for physical reasons to flag.

> "I see by glimpses now; when age comes on
> May scarcely see at all."[13]

The *visionary gleam* is instinctive,[14] and immediate,[15] and unsought,[16] "a Presence which is not to be put by." Hence it comes quite independently of the ratiocinative processes of the mind; for it is unearned—a visitation, requiring no effort to attain it.[17]

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7 "The Prelude," XII, lines 224–225.
8 *The Prelude,* Book XII, lines 224–225.
9 Ibid., Book I, line 558.
10 *The Waggoner,* IV, lines 211–212.
11 *The Prelude,* Book XII, line 599; further quotations just here are also from the end of Book XII.
12 Ibid., XII, line 203.
13 Ibid., XII, lines 281–282. This passage has been very widely misinterpreted. The physical aspect of age and decrepitude is particularly involved, and not the spiritual.
14 "Ode: Intimations," line 150.
15 Ibid., line 113.
16 Ibid., line 120.
17 Ibid., lines 115–116.

Spots of time, on the contrary, demand and involve mental effort —as Wordsworth expressly declares in dealing with them: "Thou must give, else never canst receive."[18] The mind must be "willing to work and to be wrought upon" by this type of experience.[19] And spots of time play a distinct role in the building of the mind. They are the pabulum by which experience, through sensation, feeds the developing brain. They are of "renovating virtue"; it is by these experiences, as Wordsworth pointedly declares, that "our minds are nourished and invisibly repaired."[20] In other words, the subjective experiences described by the expression "spots of time" make their mark, contribute to the mental storehouse, persist, are associated in the self-active mind, are revivable, and are clearly identifiable elements in growth of the Mind of Man from sensation, to emotionalized Fancy, to the mature Imagination.

The process is perhaps most suggestively described in the poetic passage of psychology-physiology-philosophy of *The Prelude* which begins

> "Dust as we are, the immortal spirit grows
> Like harmony in music; there is a dark
> Inscrutable workmanship . . ."[21]

Wordsworth continues here in terms that, as Beatty first demonstrated, are distinctly of the associationistic school of philosophy and psychology. The poet speaks of a "register of permanent relations" in the brain, and he insists upon the necessity of factual experience—of sensation from external stimuli—for mental perception and development.[22] The process is important to any understanding of Wordsworth's concepts of human psychology; he speaks of the

> "ties
> That bind the perishable hours of life
> Each to the other, and the curious props
> By which the world of memory and thought
> Exists and is sustained."[23]

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[18] "The Prelude," XII, lines 276–277; see also "The Excursion," IV, 1. 126.
[19] Ibid., XIV, line 103.
[20] Ibid., XII, line 210.
[21] Ibid., I, line 240.
[22] The extensive discussion in Beatty, op. cit., is pointedly endorsed by C. H. Herford (*Wordsworth,* pages 101 ff.); by Herbert Read (*Wordsworth,* pp. 184 ff.); by Ernest de Selincourt (*Prelude,* Introduction, page xxix); and by numerous other scholars. Irving Babbit ("The Primitivism of William Wordsworth, *Bookman* LXXIV, pages 1–10) makes appreciative acknowledgment of Beatty's thesis; but he completely ignores its full implications when he denies to Wordsworth's concept of Imagination any active intellectual ingredient. Though Babbitt proffers a rebuttal, the article by Joseph Warren Beach, "Expostulation and Reply" (PMLA, XL pages 346 ff.) remains a valid refutation of all denials of this sort.
[23] "Prelude" VII, 11. 461 ff.

In the famous passage quoted above he declares "there is a dark inscrutable workmanship

> that reconciles
> Discordant elements, makes them cling together
> In one society."[24]

The various forms of Nature, says Wordsworth of his early days,

> "remained in their substantial lineaments
> Depicted on the brain . . ."
> and these were
> "by invisible links
> Fastened to the affections . . ."[25]

Wordsworth is concerned with physiological processes, in all these descriptions of the Mind of Man. Our sense experiences, as positive stimuli carried to the mind over bodily nerve connections, serve "to impregnate and to elevate (in higher physical as well as ideational cortexes) the mind";[26] and they yield us "life and food For future years . . ."[27]

This heritage derives from the fact that

> "to the memory
> . . . Something cleaves at last
> Whence profit may be drawn in times to come."[28]

Our "thoughts," says Wordsworth, are "indeed the representatives of all our past feelings."[29] These subjective "elements" or ingredients, however, these "props" in mental life and growth, are not sentimental or arbitrarily to be selected and controlled. That is to say, a man cannot go out somewhere in the presence of Nature-beautiful-and-fair and "have" or induce deliberately and calculatedly a spot of time for himself. Wordsworth tells us in Book IX of *The Prelude* how he visited the ruins of the Bastille,

> "in the guise
> Of an enthusiast; yet, in honest truth,"
> he declares
> "I looked for something that I could not find,
> Affecting more emotion than I felt."[30]

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[24] Ibid., I, lines 241 ff.

[25] Ibid., I, lines 599–600; 611–612.

[26] Ibid., I, lines 596.

[27] "Tintern Abbey" 11. 64–65.

[28] The Prelude, III, 11. 627–628.

[29] "Preface," 1800. Irving Babbitt (op. cit., page 6) cites this passage deprecatingly as conclusive evidence that Wordsworth is a devotee of idle feeling and guilty of "abdication of the intellect" (cf. "The Prelude" XII, 11. 222–223). He overlooks the fundamental principle of Wordsworth's psychology here—that only intellectually approved emotion is permanently accepted by the mind as pabulum. Cf. *The Prelude* XII, 11. 276–277; XIV, 11. 106 ff., and the "Preface," "our feelings are modified and directed by our thoughts."

[30] Book IX, lines 671 ff.

This frank and shrewd recognition leads to a corollary:

Spots of time, in their chief significance as experience undergone, recorded, associated, and recollected, necessarily involve a complex psychological and physical process. The sense is stimulated, the sensation is transmitted to the brain, is received and stamped there upon neural paths and areas. An associating and connecting or relationships-establishing set of actions follows. Then whenever conditions are right, the spot of time in all its vividness can be revived, perhaps years later;[31] and it will carry enhanced value because of all implications attached to it by the maturing Imagination-Reason. The "renovating virtue" of spots of time

> "chiefly lurks
> Among those passages of life that give
> Profoundest knowledge to what point and how
> The mind is lord and master, outward sense
> The obedient servant of her will . . ."[32]

This is no sense a divorce but rather an intimate interrelationship between mind and sense.[33] It will perhaps best be illustrated in Wordsworth's own words, as quoted by De Quincey:

> " 'I have remarked from my earliest days, that if, under any circumstances, the attention is energetically braced up to an act of steady observation, or of steady expectation, then, if this intense condition of vigilance should suddenly relax, at that moment any beautiful, any impressive visual object, or collection of objects, falling upon the eye, is carried to the heart with a power not known under other circumstances. Just now, my ear was placed upon the stretch in order to catch any sound of wheels that might come down upon the Lake of Wythburn from the Keswick road: at the very moment when I raised my head from the ground in final abandonment of hope for this night, at the very instant when the organs of attention were all at once relaxing from their tension, the bright star hanging in the air above those outlines of massy blackness, fell suddenly upon my eye, and penetrated my capacity of apprehension with a pathos and a sense of the Infinite, that would not have arrested me under other circumstances.' "[34]

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[31] See the famous definition of poetry in *The Preface*, describing the process of "recollection in tranquillity." This may be glossed by innumerable passages which give the poems a consummate critical interest. And see particularly Beatty, op. cit., pages 159–168.

[32] In what is ostensibly a verbatim citation, Herford, op. cit., page 5, misquotes this passage, with consequent possibilities of wrong implication as respects the roles of "mind" and "will" in connection with the Imagination. He renders the passage "the obedient servant of *his* (Wordsworth's) will." The problem involved will appear more clearly and explicitly in our continued discussion.

[33] Wordsworth's is "a philosophy of the interrelation of the senses and the imagination." Garrod, *Wordsworth*, page 131. See *The Prelude*, XIV, 1. 76.

[34] Quoted by Beatty, op. cit., pp. 161–162, from De Quincey, *Literary Reminiscences*, Boston, 1874. The edition by Masson, cited by Melvin Rader, "Presiding Ideas in Wordsworth's Poetry," Univ. of Washington Publications in Language and Literature, Vol. 8, No. 2, fails to include this passage.

In its *origin,* as depending upon acutely active sense activity, this is a typical spot of time. In its *progress,* and its contemplation of the Infinite, it is significant as regards the essential sense-based character of the Imagination and, then, as regards its synthesizing role. The Imagination (as Wordsworth defines and traces this activity of the mind) always functions through physical processes which are anything but immediate, or independent of media.

Wordsworth in his poetry and prose is constantly paying tribute to the force and influence of objective stimuli, and to the means whereby "Nature by extrinsic passion . . . peopled" his mind with "forms sublime and fair."[35] *The Prelude* is a consistent exposition of normal mind growth from sensation through physiological paths which carry associated and associating ideas—ideas which later, as the mind matures, become the more "pure" (remote from the peripheral) thoughts to which Wordsworth frequently refers.[36] There appears mostly clearly in *The Prelude* how factual (and physiological) is the process by which the individual mind "to the external world is fitted; —and how exquisitely, too,

"The external World is fitted to the Mind."[37]

Wordsworth's argument demonstrates how, through experience of sense stimulus, followed by innate self-activity[38] of the normal healthy mind associating mental impressions, the

"common haunts of the green earth . . .
Are fastening on the heart
Insensibly, each with the other's help."[39]

It is thus factually—physiologically—that the human mind is built up "by slow gradations"[40] rather than through visitations

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[35] *The Prelude,* I, lines 545–546.

[36] Cf. Rader, op. cit., page 165: ". . . synthesis is not effected by the mind after sensation, but the sensations appear to enter into consciousness already synthesized." This interpretation offers Wordsworth gratuitous aid. According to the physiology-psychology of Wordsworth, the dark inscrutable workmanship of the subconscious mind is well able to make prompt synthesis of extrinsic impressions. (Rader mentions spots of time nowhere in his study. Perhaps he feels the term *per se* is of minor value. He makes footnote quotation of the passage containing Wordsworth's most specific treatment of the "spots" in the attempt to show that to Wordsworth "if the imagination is once active, if the mind informs the senses, then a genuine and imperishable increment of power is added to existence." This is to overlook the process of "renovation" as one of recall rather than of immediacy. A multiplicity of references in Wordsworth will testify to the informing of the mind by the senses, rather than vice versa.

[37] *The Recluse,* lines 63 ff.

[38] Rader's definition of "transcendentalism" (op. cit.) is so broad as to admit "some forms of thought" that "do not derive from experience but from the constitution of the mind." Critics are agreed that the associationistic school of philosophy never insists that the mind is *tabula rasa* originally. Wordsworth's whole concept postulates an innate self-activity in the normal mind. (See Beatty, op. cit., pp. 189–191.) (See Rader, op. cit., page 155, where "emotional, moral, intellectual, and aesthetic" forces are declared to be recognized by Wordsworth as "intuitive or transcendental". —This is contrary to innumerable claims in Wordsworth's poetry that the senses inform the mind. (Cf. "The Prelude," XII, lines 127 ff.; 214–215; 222–223; VI lines 601–602.)

[39] "The Prelude" VIII, line 120.

[40] Ibid., VIII, line 677.

that are immediate—carried, that is, without media or neural paths from the periphery, or even from cortical centers themselves.

The immediacy of the visionary gleam (as contrasted with the media-traversing, physiological processes that utilize the spots of time) has been pointed out above. The gleam may be divorced from sense experience and the material world of realities. In his youth, Wordsworth experienced "fleeting moods of shadowy exultation."

"Oft in these moments . . . bodily eyes
Were utterly forgotten . . .[41]
the fleshly ear
Forgot her functions and slept undisturbed."[42]

Phenomena of this type during childhood Wordsworth refers to in the "Ode: Intimations of Immortality" as

"those obstinate questionings
Of sense and outward things,
Fallings from us, vanishings,
Blank misgivings of a creature
Moving about in worlds not realized."

The world (to repeat) was "apparalled in celestial light" during these experiences.

It follows that whereas this visionary gleam of childhood and youth is quasi-mystical[44] and the creation of youthful Fancy, spots of time are sense-based experiences, recollectable, incorporated into our definite thinking, and elements in the mature Imagination. Imagination, it must be noted here, is Wordsworth's term for peak attainment of the Mind of Man; he uses the term in the sense of matured feeling-intellect-Reason;[43] it is essentially rooted in a mind life that has developed through factual experience and has grown from stage to stage of complexity or powers of intricate association of ideas—a Hartleyan concept soundly argued by a great school of English philosophy. "Gently did my soul put off her veil," says Wordsworth of the early visions

"and, self-transmuted, stood
Naked as in the presence of her God."[45]

As a youth, still under the dominance of Fancy, he felt

"visitings
Of the upholder of the tranquil soul
That . . . from the center of Eternity . . . lives
In glory immutable."[46]

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41 Ibid., II, lines 348 ff.
42 Ibid., II, lines 416–417.
43 "The Prelude," XIV, lines 303–304.
44 Cf. Raleigh, op. cit., pp. 94; 100; 122; 148; Legouis, op. cit., p. 103, "semi-mystical": Rader, op. cit., p. 136 "at least bordered on the mystical"; "semi-mystical," de Selincourt, op. cit., p. 513; Bernbaum, *Guide to Romanticism*, 1st edition, pp. 134 ff. These are only a few instances. They fail, however, to confine the quasi-mystical experience to childhood and youth, which as will be seen was really the limited case.
45 "The Prelude" IV, lines 150–152.
46 Ibid., 1850 version, III, lines 115 ff. The earlier versions are less orthodox.

Now the mature Wordsworth, in a pointed phrase in "The Prelude," rejects the idea of mysticism positively, and couples it with idleness and futility.[47] But his repudiation is not limited to this single utterance.[48] It is implicit or avowed in the entire body of his work; experiential psychology, with physical sensation as the starting point in mind growth, is the motif of his whole system; physical neural pathways and media are central to the ratiocination of man. This philosophy is manifested in the spots of time idea. Wordsworth's whole philosophy of the normal human mind contemplates mentality as a unit,[49] self-active, developing through sensation and the association of ideas so acquired, from infancy through successive stages to a maturity of Imagination-Reason; and when he says that Imagination *is* Reason[50] he means that the two operate in identical fashion over physical media in the brain. Much confusion of interpretation can be avoided by cleaving to this concept as a formula, so to say. It is basic in applicability to passage after passage in Wordsworth's poetry. Relevant to the present study there is a particular passage of crucial character—puzzling until this formula is remembered and Wordsworth's favorite poetic method, reminiscence, is borne in mind: A certain emotionally vivid experience discussed in *The Prelude* is termed "visionary". The poet says

> "I should need
> Colors and words that are unknown to man
> To paint the visionary dreariness
> Which, while I looked all round . . .
> Invested moorland waste, and naked pool,
> The beacon crowning the lone eminence,
> The female and her garments vexed and tossed
> By the strong wind."[51]

Is this experience, which meets essentials of what Wordsworth termed a spot of time, simply another sort of visionary gleam? Wordsworth speaks elsewhere of

> "Those recollected hours that have the charm
> Of visionary things."[52]

The "visionary gleam" is at particular times "rememberable"[53] in a definite connection with mind processes. Is any line to be drawn, after all, between a spot of time and visionary fancy?

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[47] Ibid. II, line 230.
[48] "The Prelude" II, line 419; "Tintern Abbey," lines 49–50.
[49] See Beatty, op. cit., pages 138–143; 155–165.
[50] "The Prelude" XIV, 1. 192; XIII, 1. 22.
[51] Ibid., XII, lines 254 ff.
[52] Ibid., I, lines 630–631.
[53] Ibid., I, line 588.

The solution of the entire problem is discoverable if we follow Wordsworth faithfully. The following passage will afford the key: "Even then," says this poet, of *childhood's* "vulgar joy" and "giddy bliss"

> "even then I felt
> Gleams like the flashing of a shield; —the earth
> And common face of Nature spake to me
> Rememberable things; sometimes, 'tis true
> By chance collisions and quaint accidents
> —yet not in vain
> Nor profitless, *if haply they impressed*
> *Collateral objects and appearances,*
> Albeit lifeless then, and doomed to sleep
> Until maturer seasons called them forth
> To impregnate and to elevate the mind."[54]

To Wordsworth the visionary gleam of childhood and youth, providing that it furnished definite pabulum for the association of ideas in the mind (not by any means always the case), could be lasting rather than only "fugitive"; *the gleam* held potentially the material for mind growth,[55] just as did the poet's contacts with the earth and common face of Nature. This role in the growth of the mind the *gleam* may share with *spots of time!* The simple essential requisite is that "collateral objects and appearances," significant phenomena to be "associated" or mentally related, must be stamped on the memory; and maturer seasons must bear evidence of this impression. —That is, recollection must be possible, a recollection of experience made significant through some brain activity of the glorious synthesizing faculty which Wordsworth views as a peak attainment of the Mind of Man, "the haunt and the main region of my song," and which he terms the Imagination. He couples it with Reason.

The "visionary gleam," then, is viewed by Wordsworth primarily as exciting at the time of its occurrence—in Childhood and Youth—and then "forever gone"—unless associated in constructive relationships with valid and meaningful phenomena—a gleam, say, had at one time played over some scene the developing mind, stirred by emotion, took and made contributory to its active perception of truth, of beauty, of goodness—or their opposites. The *fruitless* type of "gleam" is insubstantial, evanescent, fanciful, unpredictable, unearned, and of itself undependable—"the gleam, the Light that never was on sea or land."

Concern of the critics, and of any admirer of Wordsworth, need not be wasted over questions of "mysticism"—assuredly of rich

[54] Ibid., I, lines 585 ff. Italics added.
[55] And for the development, hence, of Imagination—and of poetry!

worth in its own right, wherever it authentically obtains. The intuitions of Wordsworth are those of a scientist of the feelings; he simply rejects an approach to experience in a "mystical and idle sense." His *spots of time,* richly felt, are intellectual building blocks; he insists on the superior importance, for poetry, of feeling over situation and actions, because feeling is a sign of activity of the mind; and ultimately all proper feeling leads along on building blocks, so to say, beyond any taint of sentimentalism into the realms of Reason.

ADOLPHE THIERS AND THE RISE OF BONAPARTISM

JACK ALDEN CLARKE
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Above the crumbling of parties, the plots and coalitions of the July Monarchy, one sentiment steadily strengthened its hold on French opinion; the cult of Napoleon. It has often been asserted, and indeed it is a predominant opinion among historians, that Louis Philippe actively encouraged this apotheosis of the glories of the Empire in order to compensate for the timidities of his own foreign policy.[1] If the prevalent view is correct, this would appear a serious blunder and the usual interpretation attributes the governmental unconcern to the seeming harmlessness of the movement. Yet an examination of the monarchy's decision to secure the return of the body of Napoleon to France in 1840, an event of singular assistance to the propagandists of the movement, throws new light on the official responsibility for the revival of Bonapartism.

The July Monarchy was not yet three months old in October of 1830 when General Maximilien Lamarque, one of the earliest and most ardent converts to Bonapartism,[2] eloquently defended in the Chamber of Deputies a petition to recover the body of Napoleon from Saint Helena and place it under the column in the Place Vendome.[3] Vigorously opposed by Charles de Lameth on the ground that there were already too many sources of discord in France, the motion was quietly shelved but not before it had provoked Victor Hugo's indignant blast at the "three hundred lawyers" in his heroic "Ode à la Colonne".[4] In the following year the petition was renewed but this time it was blocked by Lafayette and returned to the ministry without action.[5] Still another petition introduced in 1834 met a similar fate and for a time the matter rested there.

Meanwhile the revival of interest in the Napoleonic legend went on apace in France with Adolphe Thiers serving as an effective if

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[1] Jules Bertaut, *Le Retour à la Monarchie, 1815–1848* (Paris, 1943) 230–31; Margaret D. R. Leys, *Between Two Empires* (London, 1955) 207–08; James M. Thompson, *Louis Napoleon and the Second Empire* (New York, 1955) 55, 79.

[2] Lamarque was impressed by Las Cases' exposition of Napoleon's liberal ideas and converted by the report that the Emperor saw in him a future marshal. Philippe Gonnard, *Les Origines de la Légende Napoléonienne* (Paris, 1906) 335.

[3] *Procès Verbaux des Séances de la Chambre des Députés, Session de 1830.* Octobre 2, 1830 II, 30–31.

[4] Victor Hugo, *Les Chants du Crépuscule* (Brusseles, 1835) 36–49.

[5] *Procès Verbaux des Séances de la Chambre des Députés, Session de 1831.* Septembre 13, 1831 I, 588–91.

unconscious advance agent of Bonapartism.[6] While Minister of Public Works in 1833 he succeeded in re-establishing the statue of Napoleon atop the column of the Place Vendome, and in 1836 he devoted his attention to completing the Arch of Triumph in its original spirit. After his enforced retirement from the national scene in 1836 Thiers spent his time on the preparations for his ambitious *Histoire du Consulat et de l'Empire* which entailed among other things a lengthy correspondence with the Bonaparte family.[7] For the most part, his dealings with the Bonapartes were on the friendliest of terms, and during the next decade he served as their tireless but unofficial champion, endlessly seeking pensions and other favors for members of the family.[8] Although this carefully fostered rehabilitation of the Emperor was advanced by such popular literary men as Berenger and Hugo, it did not lack critics, and as early as 1832 Heine prophetically remarked that a thousand cannon sleep in the name Napoleon even as in the shaft of the Vendome column.[9]

In 1838, Thiers began a regular campaign of parliamentary opposition which in March of 1840 made him president of the Council of Ministers and foreign minister for the second time. As in 1836, he was swept into office on a wave of nationalistic sentiment, largely of his own making, and was forced to adopt a vigorous, imaginative policy in order to distract the public from its momentary concerns. Lacking a majority for his ministry, Thiers had to depend on his own group, the Left Center, and on the remains of Molé's party then known as the 221. Opposed to him were the Legitimist Right, the Right Center which did not want a warlike policy, and the Left which demanded the repeal of the September laws and the reform of the election taxes.[10] In opposition, Thiers had continually harped on the timidity and narrowness of view of his predecessors and, now in power, he hoped to prove himself the most national spokesman of the new monarchy.

Shortly after the formation of his cabinet, Thiers broached the idea of requesting the body of Napoleon from Great Britain to the

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[6] In Jerome Bonaparte's opinion Thiers' actions may have been deliberately intended to weaken the prestige of the monarchy and thereby render himself indispensable. Ernest Daudet, *Souvenirs de mon Temps, Débuts d'un Homme de Lettres 1857–1861* (Paris, 1921) 156.

[7] *Une Page d'Histoire Contemporaine, M. Thiers et les Napoléons, Lettres et Documents Inédits 1837–1848* (Paris, 1873) passim.

[8] Thiers used his credit with Louis Philippe in an attempt to exempt Jerome from the provisions of the law of 1832 exiling the Bonapartes. A letter written to Jerome in 1837 is typical: "Je suis, vous le savez, l'un des français de ce temps les plus attaché à sa (Napoleon's) glorieuse mémoire et je serai heureux quand je verrai le retour des parents qui lui apartiennent se concilier avec le repos de notre pays et le maintien de son gouvernement" Jerome Bonaparte, *Mémoires et Correspondance du Roi Jerome et de la Reine Caroline* (Paris, 1866) VII, 488.

[9] Heinrich Heine, *Das Burgerkonigthum in Jahr 1832* (New York, 1879) 145.

[10] Charles Seignebos, *A Political History of Europe since 1814* (New York, 1879) 145.

Duke of Orleans who in turn passed it along to his father. At first Louis Philippe seems to have rejected the plan,[11] but on May 1 at a party in the Tuileries he announced his acceptance with the characteristic remark that it would have been forced from him eventually by petitions and he preferred to concede.[12] With the consent of the king, Thiers charged Lord Granville, the British Ambassador at Paris, to send a preparatory message to his government, and on May 4 he informed Guizot, then Ambassador at London, of his intentions.

"The king consents to transport the remains of Napoleon from Saint Helena to the Invalides. He is as enthusiastic as I am which is not saying a little. This must be obtained from the English cabinet . . . Conduct the affair so that we may speak or be silent in case of a refusal. Lord Granville does not believe a refusal possible. If the request is accorded a ship will leave immediately to seek out the body. It will be necessary for an English commissioner to go along to secure the restitution. Succeed in this affair and we will leave all of the honor to you."[13]

Momentarily, Guizot relates, he was both surprised and apprehensive at these instructions, but he soon banished his doubts and accepted his role leaving the responsibility for its consequences to the ministry. Although Lord Palmerston greeted the French request cordially and with seeming approval, Guizot thought he detected a faint smile on his face. Privately Palmerston remarked that "it would have been foolish in us not to have granted it and we have made a merit of doing so readily and with a good grace".[14] As soon as the British cabinet had unofficially approved the transfer, a formal request was submitted through Guizot and on May 10, just six days after the original communication, the official British acceptance was sent to Granville at Paris. It was agreed that a British ship, the Dolphin, would carry the order for the transfer to the Governor of Saint Helena, and an authentic copy of the document was to be given to Joinville.[15] With these preliminaries concluded, Thiers was now in a position to present his project to the Chamber of Deputies for its endorsement.

On May 12 in the midst of an interminable discussion of sugar legislation Count Charles de Remusat, the Minister of the Interior, ascended the tribune and proceeded to unfold the plan of the government. Secret negotiations, he disclosed, had been concluded with

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[11] Paul Thureau-Dangin, *Histoire de la Monarchie de Juillet* (Paris, 1897–1904) IV, 158–159.

[12] Jean Lucas-Dubreton, *Aspects de Monsieur Thiers* (Paris, 1948) 129.

[13] François Guizot, *Mémoires pour Servir à l'Histoire de Mon Temps* (Paris, 1862) V, 106–107.

[14] Lord William Dalling and Bulwer, *The Life of Henry John Temple Viscount Palmerston* (London, 1874) III, 39.

[15] Louis Eustache Audot, *Les Funérailles de l'Empereur Napoléon* (Paris, 1841) 11.

Great Britain for the transfer of the body of Napoleon to France, and the Prince de Joinville had been commissioned by the king to sail for Saint Helena in the near future. Napoleon, Remusat pointed out, was a legitimate sovereign[16] and was entitled to be buried in the royal sepulchre at Saint Denis, but this seemed insufficient for such a great captain and the ministry required a credit of one million francs to prepare an appropriate tomb in the Invalides.

"The government of July," Remusat argued, "is indeed the sole legitimate heir of all the memories of which France is so proud. It was fitting doubtless for the monarchy which first has rallied all of the forces and conciliated all of the vows of the French Revolution to erect and to honor without fear the tomb of a popular hero, for there is one thing only that does not dread comparison with glory, that is liberty."[17]

The reading of Remusat's speech was interrupted several times by lively applause and at its conclusion the session was temporarily suspended to allow the enthusiasm to wear itself out.[18] "Isn't this a fine gesture?" Thiers remarked to Duvergier de Hauranne, one of the more advanced deputies of the left who managed to resist the general enthusiasm. "Yes," Duvergier replied, "it is a good joke."[19]

Initially public reaction to Thiers proposal was overwhelmingly favorable with even the anti-ministry papers endorsing the restoration. A special parliamentary committee headed by Marshal Clausel unanimously recommended an augmentation of the credit to two million francs and the dispatch of a squadron to Saint Helena instead of a single vessel. In the first rush of excitement some Bonapartists proposed the erection of an equestrian statue of Napoleon as one of the honors due to a crowned head while others equally enthusiastic suggested that the effigy of Henry IV be removed from the medal of the legion of honor and replaced by the eagle and countenance of the Emperor.[20] Napoleon, Delphine de Girardin remarked, "has been cursed, hated, betrayed, even forgotten and now those who cursed him admire him, those who hated him adore him, and those who betrayed him weep for him."[21]

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16 Shortly after the attempted coup d'état of August 20 Metternich commented on this assertion, "Si M. Rémusat a eu raison il est clair que Louis Napoléon n'a point eu tort." Clemens Metternich-Winneberg, *Mémoires, Documents et Écrits Divers* (Paris, 1883) VI, 442.

17 *Le Moniteur Universel.* May 13, 1840.

18 Elias Regnault, *Histoire de Huit Ans, 1840–1848* (Paris, 1860) I, 141.

19 Thureau-Dangin, *Histoire de la Monarchie de Juillet,* III, 155.

20 Esprit Victor Castellane, *Journal du Maréchal de Castellane 1804–1862* (Paris, 1896) III, 218. The effigy of Henry IV was not replaced by that of Napoleon as consul until Sept. 12, 1848. Jean Daniel, *La Légion d'Honneur, Histoire et Organisation de l'Ordre National* (Paris, 1948) 78.

21 Delphine de Girardin, *Le Vicomte de Launay, Lettres Parisiennes* (Paris, 1856) II, 191.

When the first moments of enthusiasm had passed, many cooler heads began to examine the merit of Thiers' scheme and to weigh its logical consequences. How, they asked, could one prevent the attendance of the Bonaparte exiles at this state funeral and what was to be done about the self styled imperial heir Louis Napoleon.[22] "Thiers himself," Lamartine noted, "is in the hands of the passions he has kindled . . . The ashes of Napoleon are not extinguished and he blows on them. God save us."[23] On May 22, the *Journal des Débats* cautioned against the excessive enthusiasm of sending a squadron to Saint Helena,[24] but four days later when Lamartine resolved to denounce this idolatry of the Emperor he found himself deserted by his own party and was forced to change his speech at the last minute.[25] Inside the Tuileries there were misgivings since the Queen had little taste for the plan or its author,[26] and from Brussels Louis Philippe's daughter Louise warned that there must be no continuation of this comedy.[27] Alarmed by the feverish popular interest in the restoration, the deputies rebuffed the commission's request for another million and instead of an anticipated victory the ministry suffered its first parliamentary check on this relatively unimportant matter.[28]

Much to the discomfiture of the ministry which hoped to ignore this adverse vote, several journals promptly initiated a popular subscription to make up the second million by gifts from their readers. Although their appeal was phrased in emotionally dramatic terms it fell on deaf ears and contributions amounted to only 25,000 francs after several days.[29] Yet the campaign continued until June 1 when a public letter written by Odilon Barrot and undoubtedly instigated by Thiers cited such compelling reasons for not subscribing that the *Courrier Français* announced it was returning the money already collected.[30]

In the meantime, while the entire nation watched with keen interest, the government was quietly assembling the official party which was to accompany Joinville on the Belle Poule.[31] Generals Bertrand and Gourgaud, old companions in captivity of the Emperor, and the son of Count Las Cases were included as were four

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[22] Ximines Doudan, *Mélanges et Lettres* (Paris, 1878) I, 323.
[23] Alphonse de Lamartine, *Corréspondance de Lamartine* (Paris, 1881–84) IV, 53.
[24] *Journal des Débats*. May 22, 1840.
[25] Lamartine, *Corréspondance,* IV, 57–58.
[26] Auguste Trognon, *Vie de Marie Amélie* (Paris, 1871) 287.
[27] Louise Marie d'Orléans, *Lettres Intimes de Marie Louise d'Orléans, Première Reine des Belges au Roi Louis Philippe et à la Reine Amélie* (Paris, 1933) 109.
[28] Noailles, however, felt that Thiers had lost little prestige from this fiasco. Dorothée Talleyrand–Périgord, *Chronique de 1831 à 1862* (Paris, 1909) II, 298. This view was shared by an anonymous observer in the "Chronique de Quinzaine" *Revue des Deux Mondes,* May 14, 1840, II, 717.
[29] Thureau–Dangin, *Histoire de la Monarchie de Juillet,* IV, 166.
[30] Castellane, *Journal.* III, 219.
[31] François Poumié de la Sicotière, *Recollections of a Parisian* (New York, 1911) 267.

of the former imperial domestics. At first the young prince, then recuperating from an attack of chicken pox, showed considerable reluctance to undertake this tedious and uncongenial mission but he subsequently reconciled himself to his assignment in the romantic notion that by seeking out the ashes of Napoleon he was raising the standard of a vanquished France.[32] Only after the ships had sailed on July 7 was he informed that the real commander of the expedition was to be Thiers' agent, the young Count de Rohan-Chabot. In this manner Thiers asserted his independence of the monarchy.

The voyage westward was a leisurely affair filled with good conversation and such lengthy stopovers that it was not until October 8 that the French ships sailed into the harbor of Jamestown amid friendly salutes from British batteries and ships of war anchored in the roadstead. Work on the excavation of the tomb began soon after midnight on the 15th, the twenty-fifth anniversary of the arrival of Napoleon at Saint Helena, but it was 9 a.m. when the coffin was exposed to view, raised, and opened.[33] "It was indeed Napoleon," young Las Cases wrote in his journal, "Napoleon deprived of life but not destroyed."[34] After a brief examination the body was transferred to another coffin brought from France and transported to the point of embarkation. On October 18, in the midst of the second Mehemet Ali crisis which threatened momentarily to lead to a general European war, the French ships set sail for Cherbourg. Their return had been scheduled by Thiers for the beginning of December, the time of the reconvening of the Chamber of Deputies, but in spite of his shrewd calculations Thiers' ministry had fallen thirty-four days before the Belle Poule dropped anchor at Cherbourg.

On December 8 amid the booming of a thousand cannon the remains of Napoleon were placed on a coastal schooner which took the coffin to Havre where it was transferred to a flat bottomed barge.[35] Everywhere as the funeral barge moved up the Seine there was gaiety and rejoicing and in some localities spectators lined the banks for miles in double ranks. At Courbevoie, just outside of Paris, the coffin was placed on a magnificent hearse specially constructed to carry the remains of the Emperor to their final resting place. Precisely at eleven on the morning of December 15 the solemn procession began to move along a line of march elaborately decorated with incense burners, banners, and plaster statues, most of them sorry examples of French taste.[36] Alarmed by rumors of a

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[32] François de Joinville, *Vieux Souvenirs 1818–1848* (Paris, 1894) 207–08.

[33] Audot, *Les Funérailles de Napoleon*, 14.

[34] Emmanuel de Las Cases, *Journal Écrit à Bord de la Frigate Belle Poule* (Paris, 1841) 56.

[35] Audot, *Les Funérailles de Napoleon*, 33–34.

[36] Victor Hugo, *Things Seen* (New York, 1887) I, 27.

popular insurrection, the ministry, headed by the cautious Guizot, stationed cavalry at several points along the route, which prompted Thiers, now a mere observer, to complain that the government was stifling the national spirit.[37] Perhaps due to the presence of troops but more likely to the intense cold, the great crowd estimated at over 600,000 was strangely silent and there were but few incidents, such as a red flag here and there[38] and scattered shouts of "À bas les traitres".[39] At two P.M. the cortege arrived at the Invalides where after a grandiloquent but somehow moving ceremony the body of the Emperor was laid to rest in St. Jerome's chapel where it remained until twenty years later, when it was placed beneath the lovely dome of Louis XIV. That evening, at a reception in the Tuileries, Louis Philippe publicly commended Guizot for preventing an insurrection, remarking that he would have risked losing his throne if Thiers had still been minister.[40]

Judged by any valid standards of statesmanship, this attempt to secure cheap popular support by extolling the military triumphs of the Empire constitutes a political miscalculation of the first magnitude for both Thiers and the monarchy he served. Not only did it fail to offset Thiers' unpopularity with the court party but it alienated the legitimists by implying that the pretensions of the Comte de Chambord and Louis Napoleon were of equal validity.[41] Moreover, the elaborate reburial failed to satisfy Bonapartist expectations and only succeeded in making the French the laughing stock of Europe.[42] If anyone profited from the incident it was the radicals and republicans who appropriated the memory of Napoleon and used it to their advantage.

It was the failure and misfortune of Louis Philippe and his advisers that they, like Thiers, did not appreciate the full seriousness of the situation. "The idea of a Napoleonic monarchy," Louis de Carné wrote, "functioning regularly after the fall of that of 1830 is political nonsense so evident that a serious man doesn't even have to discuss it."[43] Years later Guizot remarked that he did not regret the restoration since it had little to do with the power

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[37] Karl Robert Nesselrode, *Lettres et Papiers du Chancelier Comte de Nesselrode 1760–1850* (Paris, 1904–1912) VIII, 89.

[38] Talleyrand–Périgord, *Chronique de 1831 à 1862,* II, 437.

[39] Joinville, *Vieux Souvenirs 1818–1848,* 224.

[40] Nesselrode, *Lettres et Papiers,* VIII, 93. This view was shared at St. Petersburg where Barante was congratulated when no uprising took place. Amable Guillaume Barante, *Souvenirs du Baron de Barante 1782–1866* (Paris, 1890–1901) VI, 553.

[41] Alexandre Dumas, *Histoire de la Vie Politique et Privée de Louis Philippe* (Paris, 1852), II, 213–14.

[42] See Thackeray's celebrated burlesque of the incident originally published in the *Cornhill Magazine.* William Makepeace Thackeray, "The Second Funeral of Napoleon" in *Roundabout Papers* (London, 1869) 377–428.

[43] Louis de Carné, "De la Popularité de Napoléon" in *Revue des Deux Mondes,* June 1, 1840, II, 867.

of the Napoleonic name in 1848.[44] But as subsequent events proved, practical politicians are sometimes unskilled at reading the signs of the time and the Bonapartist propagandists took full advantage of the opportunity presented. By advancing the Napoleonic legend as a permanent rebuke to Louis Philippe's policy of conciliation, Thiers contributed to the fall of his royal master and rendered suspect his own reputation as a farseeing statesman.

[44] Guizot, *Mémoires pour Servir à l'Histoire de Mon Temps*, VI, 22.

TENNYSON AT CAMBRIDGE: A POET'S INTRODUCTION TO THE SCIENCES*

FREDERICK I. TIETZE
University of Wisconsin Extension Division, Racine†

Certain dualisms in the thinking of western man are so firmly, habitually established as to be numbered among his unquestioned assumptions. Ordinarily, the polar separation of good and evil, of subjectivity and objectivity, of heaven and hell, is as unquestioningly accepted as the separation of north and south, of right and left. Science and poetry, when thought of together are thought of as another set of paired opposites, and the familiar divisions in a college or university faculty, in the arrangement of books in a library, in the lists of a publishing house, are commonplace testimonies of this separation. But now and again the great polarities are merged, and when they are well-merged, the occasion is notable. Blake arranged the marriage of heaven and hell; Coleridge presented a poetic vision of good and evil in which these mighty opposites take on an unexpected ambiguity. Alfred Tennyson demonstrated that science and poetry share some vital ground in common.

Though others among Tennyson's contemporaries noted his alertness to the new forces of science, the commendation which carries most weight is the one by the most militant of nineteenth-century scientists. Thomas Huxley pointed to Tennyson as "the only poet since Lucretius who has taken the trouble to understand the work and tendency of the men of science."[1] A. C. Bradley, if less the scientist than Huxley, could speak with more than Huxley's assurance as a literary critic:

> With the partial exception of Shelley, Tennyson is the only one of our great poets whose attitude toward the sciences of nature was what a modern poet's attitudes ought to be . . . the only one to whose habitual way of seeing and thinking it makes any real difference that Laplace or, for that matter, Copernicus ever lived.[2]

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† Now at Southern Illinois University.

[1] Leonard Huxley, *Life and Letters of Thomas Henry Huxley,* 2 vols. (New York, 1901), II, 350.

[2] "The Reaction Against Tennyson," *A Miscellany* (London, 1929), p. 31.

John Burroughs, naturalist and man of letters, offered this further testimony:

> Whitman and Tennyson were the only poets of note in our time who have drawn inspiration from modern science or viewed the universe through the vistas which science offers.[3]

Critics in our own century who have denied any great profundity in Tennyson might dismiss these testimonies by saying that Tennyson merely absorbed this regard for science from his time. Progress was in the air and progress owed much to science. Tennyson, with his usual facility, these critics might say, and out of regard for his public function as poet laureate, put on an alertness to science.

Such a dismissal of Tennyson's interest in the natural sciences would be neither accurate nor just, for that interest was not imposed from without. It arose from certain qualities deeply embedded within the poet's nature, qualities discernible in his boyhood and operative as well during his years at Cambridge. It is on these years at the university, 1828–1831, that I wish to focus attention. Tennyson's biographers have taken notice of the Cambridge years chiefly for the associations which the poet began at that time, most notably his membership in that little society of undergraduates, the "Cambridge Apostles," whereby he became the friend of Arthur Hallam whose untimely death gave the initial impetus for the long elegiac poem, *In Memoriam.* Important as these activities were, they were still extra-curricular. On the other side were the academic interests, duller perhaps, but nevertheless the ostensible reasons for any student's matriculating at Cambridge. Something, therefore, of the scientific tone of Cambridge in the late 1820's is pertinent.[4]

If one were to make simply a university-catalog judgment, one might be justified in saying that the natural sciences were in a flourishing state. Of the ten university professorships which had been established during the eighteenth century, eight were dedicated to those sciences after the modest beginning in the seventeenth century with the Lucasian chair in mathematics. Doubtless the several donors hoped that, as Newton had shed luster on the name of Henry Lucas, so might their names be immortalized. But four of these professorships suffered from the circumstances then prevailing at Cambridge (and at Oxford as well), namely, college ascendancy. Students were responsible to their colleges and took examinations set by their colleges, whereas the professorships were intended to serve the university at large. Thus, attendance at professorial lectures was strictly an elective matter, and dropped so

[3] "Relation of Whitman and Tennyson to Science," *The Dial,* XIV (1893), 169.

[4] G. R. Potter called attention to these academic interests in his "Tennyson and the Biological Theory of Mutability of Species," *Philological Quarterly,* XVI (1937)..

low at times that the course of lectures was perforce dropped also, but the professorship went on uninterrupted and became, of course, a sinecure. Parliament and the great national reviews, scandalized by this state of affairs, investigated and discussed at great length its cause and possible cure. University reform remained an issue for forty years.[5]

But meanwhile the picture was not entirely dark. William Farish, Jacksonian Professor of Natural and Experimental Philosophy, regularly enrolled the then-large number of eighty students in his class.[6] The applications of science to the arts and manufactures of England, "particularly such as relate to Chemistry," were his specialty. One wonders at the amorphous condition of that science as one surveys his subjects: mining and smelting, all kinds of manufacturing, the problems of inland navigation, the construction of bridges, aqueducts, locks, ships, docks and harbors.[7] More strictly scientific in our eyes was the Woodwardian chair in geology held by Adam Sedgwick. His appointment in 1818 was not particularly auspicious, for he admitted knowing nothing about geology, but he kept so well his promise to "get up" the subject that he was credited with having "completely transformed both the character of the professorship and the status of geology in the university."[8] Classification of the fossils of mammals and study, in association with Murchison, of the sedimentary rocks kept him busy in research. In teaching, he knew the value of enthusiasm and the practical necessity of field trips. It was distinctly probable that from his attending at least one such field trip, Tennyson drew the material which a dozen years later he wove into a passage of *The Princess,* describing how the heroine of that poem and her party "rode to take the dip of certain strata to the north":

> We turned, we wound,
> About the cliffs, the copses, out and in
> Hammering and clinking, chattering stony names
> Of shale and hornblende, rag and trap and tuff,
> Amydaloid and trachyte till the sun
> Grew broader toward his base and fell.

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[5] A pair of articles in the *Edinburgh Review* in 1810 brought the matter to public attention. Specific contributory abuses were discussed by Charles Lyell in *Travels in North America* (New York, 1845) vol. II, by Charles Merivale in *Autobiography of Dean Merivale with Selections from his Correspondence,* Judith A. Merivale, ed. (London, 1899), by Charles Astor Bristed in *Five Years in an English University* (New York, 1852); and these abuses have been well-summarized by D. A. Winstanley, *Unreformed Cambridge* (Cambridge University Press, 1935). The official investigation is recorded in "Report of Her Majesty's Commission to Inquire into the State, Discipline and Finances of Cambridge University," *British Parliamentary Papers,* 1852–53, Vol. XLIV.

[6] *Quarterly Review,* (1827), p. 263.

[7] See R. T. Gunther, *Early Science in Cambridge* (Oxford University Press, 1937), p. 231.

[8] Winstanley, p. 171.

Another professorship of happy record was J. S. Henslow's tenure as Professor of Botany.[9] Like Sedgwick, Henslow conducted field trips which were very popular among all students, botanical and otherwise. Charles Darwin has left a glowing account of Henslow the man and the teacher. "Quite the most perfect man I ever met with" said Darwin.[10] Mathematics was Darwin's bugbear, and Henslow's coaching seems to have been necessary for Darwin's inglorious tenth place in the Mathematical Tripos of 1831. At a time when Darwin was thoroughly unsettled over his career, positive only that it would not be medicine, he had, he said, "some thoughts of reading divinity with Henslow," but Henslow's eventual role in Darwin's accompanying the *Beagle* expedition was his truly decisive contribution to the young naturalist's career. It might be noted in passing that the paths of Tennyson at Trinity College, Darwin at Christ's College seem never to have crossed at all. In Darwin's world even "Cambridge Apostle" meant one of the lower twelve men in the Mathematical Tripos, a class to which Christ's College contributed many members.[11]

Henslow and Sedgwick were co-founders of the Cambridge Philosophical Society in 1820. The society was meant to be "a point of concourse for scientific communication," and in this aim it succeeded, just as it did in broadening the range of scientific study at Cambridge away from the mathematics-mechanics-astronomy triad.[12] Although it was open only to Cambridge graduates and Tennyson necessarily remained beyond the pale, for he never did take his degree, yet the society contributed significantly to the intellectual climate. Graduates, professors, tutors, fellows, and coaches to the number of 171 from its first year became members. In 1831 William Whewell reviewed the third volume of the Society's *Transactions* and used the volume as proof, at Cambridge, of "intellectual activity, of zeal for science, of perseverance and intelligence in its prosecution, of familiarity with the most valuable portions of recent discovery."[13]

Even though we view them critically, the university professors of science at Cambridge wielded an influence to which Tennyson was sensitive. Scientific inquiry from its Greek beginnings has always had certain implications for the human spirit. One of these implications found expression for the nineteenth century in the words of the Earl of Rosse as he made the presidential address

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[9] See, for example, "The State of the Universities," *Quarterly Review*, XXXVI (1827), p. 263.

[10] *Life and Letters of Charles Darwin, Including an Autobiographical Chapter*, Francis Darwin, ed. 2 vols. (New York, 1919), I, '58.

[11] *Ibid.*, I, 159.

[12] See Robert C. Stauffer, "The Introduction of Modern Laboratory Science in the English University System," unpublished doctoral dissertation (Harvard, 1947), p. 53.

[13] *British Critic* No. 17. Cited by Isaac Todhunter, *William Whewell D.D.* 2 vols. (London, 1876), II, 49.

before the British Association in 1843: "Science claims as one of its noblest attributes, the power of enlarging and ennobling the mind."[14] It was just this implication of which Tennyson took notice in "Timbuctoo," the poem with which he won the Chancellor's Prize at Cambridge in 1829. This, a reworking of an earlier poem entitled "Armageddon," contained as its central theme the vision of a seer, the speaker of the poem:

> I seem'd to stand
> Upon the outward verge and bound alone
> Of God's omniscience. Each failing sense,
> As with a momentary flash of light,
> Grew thrillingly distinct and keen. I saw
> The smallest grain that dappled the dark Earth
> The indistinctest atom in deep air,
> The Moon's white cities, and the opal width
> Of her small, glowing lakes, her silver heights
> Unvisited with dew of vagrant cloud,
> And the unsounded, undescended depth
> Of her black hollows.

These lines, present in the earlier "Armageddon" and retained in "Timbuctoo," demonstrate Tennyson's close attention to the observed fact and they sound a theme which was to mature more fully in later poems: science as an avenue to fuller consciousness, to a fuller sense of being; science, thus, as an affirmation of the human spirit. In the Cambridge poem, Tennyson extended the passage, reflecting at once his unabated interest in astronomy,[15] an interest aroused in his boyhood through his acquaintance with the work of the elder Herschel, and reflecting too the lively interest in astronomy of the university itself, where a new observatory had been opened in 1828 under Professor Airy's direction.

> The clear galaxy
> Shorn of its hoary lustre, wonderful,
> Distinct and vivid with sharp points of light,
> Blaze within blaze, an unimagine'd depth
> And harmony of planet-girded suns
> And moon-encircl'd planets, wheel in wheel
> Arch'd the wan sapphire.

In another poem of the Cambridge years, "The Palace of Art," which circulated in manuscript among the poet's friends, Tennyson allegorized the "art for art's sake" question some decades before that question became more publicly discussed. Science as science is not prominent in this poem, but knowledge, like art, Tennyson

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[14] *Report of the British Association for the Advancement of Science* (London, 1844), p. xxxii.

[15] Tennyson's interest in astronomy remained, in fact, lifelong. See for example Hallam, Lord Tennyson, *Tennyson: A Memoir,* 2 vols. (London, 1898), I, 385; II, 408, and Ada Pritchard, ed. *Charles Pritchard, D.D.; Memoirs of His Life* (London, 1897).

moralized, cannot be enjoyed in exclusion by those who alone are versed in it. Having rejoiced in her "Godlike isolation," Art presently likened herself to

> A still salt pool, lock'd in with bars of sand,
> Left on the shore, that hears all night
> The plunging seas draw backward from the land
> Their moon-led waters white;
>
> A star that with the choral starry dance
> Join'd not, but stood and saw
> The hollow orb of moving Circumstance
> Roll'd round by one fix'd law.

Four years of painful separation left Art chastened. Her restoration to human society was to take place in one of those domestic settings which were among Tennyson's favorites:

> She threw her royal robes away.
> 'Make me a cottage in the vale,' she said
> Where I may mourn and pray.
>
> 'Yet pull not down my palace towers, that are
> So lightly, beautifully built;
> Perchance I may return with others there
> When I have purged my guilt.'

Baldly stated, art and knowledge must be humanized.

The closest connections formed by any student at Cambridge were those within his college. This was natural since the colleges dominated the university itself and the chief instruments in this domination were the college tutors, aided by their unofficially recognized allies, the private tutors or coaches. Among the colleges, the one uniformly prevalent teaching discipline was mathematics. The highest honors which students could achieve at Cambridge were awarded for excellence in this field.[16] The Classics Tripos, instituted in 1824, was still on sufferance in Tennyson's time and as for the natural sciences, examinations of comparable importance were not to be established until 1848. In the overall view, the college system at Cambridge was not designed to educate young men in natural science, and the university professorships, though designed for this purpose, did not succeed very well in doing so.

Other shortcomings in the college system were diagnosed typically by Lyell. He charged that college ascendancy meant incompetent instruction, since college tutors were ordinarily too young to discharge the duties required of them and of too short a tenure, waiting as they often were for preferment in the church, to gain

[16] Charles Darwin was not the only student to be handicapped by this circumstance. John Wordsworth, nephew of the poet, was another, as was Frederick Tennyson, Alfred's elder brother, and Charles Merivale of the Tennysons' circle. See *Autobiography of Dean Merivale,* p. 53.

the experience and the learning they needed. Particularly he objected to the impossibility of specialization, when "two or three individuals, and occasionally a single instructor, may be called upon to give lectures in all the departments of human knowledge."[17]

But at Trinity College, which is after all our particular concern, there were extenuations. Trinity was large enough to afford more than the two or three tutors whom Lyell decried, and among the staff in the 1820's were some remarkably able men. George Peacock, Connop Thirlwall, Julius Hare, George Airy—all were Trinity men and all were to achieve eminence. But the Trinity man who stands at the very center of many a Cambridge matter in our period, a champion of college ascendancy but very active in raising the university professorships to their deserved place; an outspoken defender of mathematics as a teaching discipline, but hardly less attentive to classics for the same purpose; outstandingly cognizant of the new natural sciences, keeping abreast of them while not losing touch with the old—this was William Whewell, fellow and tutor of Trinity College, the man under whose care, along with perhaps forty other youths, came Alfred Tennyson.[18]

The rise from a carpenter's family to the Mastership of Trinity College was not exactly a rare sort of occurrence in nineteenth century England, but that it happened in tradition-bound Cambridge must be credited to the character of Whewell. His temper was not the sort which would have made him especially close to his students. "Bulldog Whewell," or "that very worthy but somewhat dictatorial Whewell" are tags which testify to the distance between him and his pupils. He himself dreaded term-opening and his first meeting with freshmen, partly because he felt himself not particularly fitted by nature for such encounters, and partly because it meant the resumption of teaching duties when his own researches were much more attractive. On one occasion he complained "my tutorship hangs about the neck of my theories in a wonderful manner—I mean in the way of a millstone and not of a mistress."[19]

Whewell, like John Donne, suffered from "an hydroptick love of learning," and it was partly this love which led him to make Cambridge his career. Sir John Herschel said of him "that a more wonderful variety and amount of knowledge in almost every department of human inquiry was perhaps never in the same interval of

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17 Charles Lyell, *Travels in North America,* 2 vols. (New York, 1845), II, 241.

18 For his work in mathematics see Merivale, *Autobiography,* p. 60, and Whewell, *Thoughts on the Teaching of Mathematics* (Cambridge, 1835). For his generalized views on education, see *Principles of English University Education* 2d ed. (London, 1838), and *Of a Liberal Education in General* (London, 1845). Whewell reviewed enthusiastically J. F. W. Herschel's *A Preliminary Discourse on the Study of Natural Philosophy* (See *Quarterly Review,* 1831) and that book, a copy of which was owned and annotated by Tennyson, helped to set Whewell on to his own fuller *History of the Inductive Sciences* (1836), followed by *Philosophy of the Inductive Sciences* (1840).

19 Todhunter, II, 62.

time accumulated by any man."[20] Charles Astor Bristed, in residence at Cambridge when Whewell succeeded Christopher Wordsworth as Master of Trinity, reported that

> In conversation it was scarcely possible to start a subject without finding him at home in it. . . . The mass of his general knowledge taken together constituted his strength. There were few men of like pretensions to weigh or appreciate this; he was judged piecemeal . . . by men whose whole development and training was partial. Sidney Smith's saying of him "that omniscience was his forte and science his foible" was very generally circulated and applauded.[21]

Decades later Tennyson added his own footnote corroborating Whewell's learnedness. A bit of undergraduate doggerel had been circulating at Oxford at the expense of Benjamin Jowett:

> What I know not is not knowledge,
> I am the Master of this college.

Tennyson upon hearing it retorted "Very unfair. Jowett never set up to be omniscient. It might possibly have suited Whewell."[22] Tennyson's first long poem, *The Princess,* is profuse in its allusions to Cambridge, and the scene in one passage, although its central figure has been metamorphosed into a woman—the Princess of the title who heads a girls' academy—the scene must have been modelled by Whewell:

> On the lecture slate
> The circle rounded under female hands
> With flawless demonstration; followed then
> A classic lecture, rich in sentiment,
> With scraps of thunderous epic lilted out
> By violet hooded Doctors, elegies
> And quoted odes, and jewels five-words-long
> That on the stretch'd forefinger of all Time
> Sparkle forever. Then we dipt in all
> That treats of whatsoever is, the state,
> The total chronicles of man, the mind,
> The morals, something of the frame, the rock
> The star, the bird, the fish, the shell, the flower
> Electric, Chemic laws, and all the rest,
> And whatsoever can be taught and known.
> II, 349–363.

Something of Whewell's enthusiasm for knowledge unquestionably was absorbed by his pupil Tennyson. "Let knowledge grow from more to more" was to become part of the burden of *In Memo-*

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[20] *Ibid.*, I, 1.
[21] *Five Years in an English University* (New York), 1852), pp. 88–89.
[22] *Memoir,* II, 400.

riam, but one finds that theme anticipated in the following portion of an unpublished sonnet from the Cambridge years:

> Why suffers human life so soon eclipse?
>
> . . .
>
> Would I could pile fresh life on life and dull
> The sharp desire of knowledge still with knowing
> Art, Science, Nature, everything is full,
> As my own soul is full to overflowing—
> Millions of forms, and hues, and shades that give
> The difference of all things to the sense,
> And all the likeness in the difference.
> I thank thee, God, that thou hast made me live:
> I reck not for the sorrow or the strife:
> One only joy I know, the joy of life.[23]

The poem falls well short of greatness, and Tennyson very properly left it as a manuscript, for it simply states rather than convinces us of its author's exuberance. But the same theme of thirst for knowledge was to be dramatized with full success in Tennyson's later poem, "Ulysses."

Looking back to his student days some forty years later, the poet complained that "there was a want of love at Cambridge then," and one of his Cambridge poems attests to this lack.[24] Others have left testimony in the same vein.[25] Darwin seems to have had a flair for getting around the pale that separated dons from undergraduates, but even Darwin's reputation as "the man who walks with Henslow" is perhaps evidence of the rarity of such a relationship. Whatever remoteness the ordinary student may have felt from the official agents of his college and from the university, it remains a fact that Tennyson set himself after his return home to Somersby a program of studies which, along with history, languages, and theology, included botany, chemistry, mechanics, electricity, and "animal physiology."[26] Whatever the personal deficiencies he may have found at the several levels of instruction, Cambridge had impressed him with the impersonal significance of the natural sciences.

No impulse to enroll himself in the ranks of the scientists seems ever to have seized Tennyson; he remained the poet. His responses to scientific inquiry were ultimately and most importantly esthetic; he translated into poetry that enthusiasm for knowledge which men

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[23] *Ibid.,* I, 59.

[24] *Ibid.,* I, 67–68.

[25] See Merivale, *Autobiography,* p. 58; Lyell *Travels,* II, 230. Winstanley deals with college tutors' abuse of their prerogative in setting examinations, *Unreformed Cambridge,* p. 64. The Royal Commission found similar instances of the college tutors' autonomy. "Report," p. 64.

[26] *Memoir,* I, 124.

like Whewell and Henslow and Sedgwick exemplified. To know as science made one know was to be energized, not enervated, and the recurrently melancholic Tennyson—Auden has said with truth "he knew all that was to be known about melancholy"[27] seized eagerly upon a life-affirmation as vigorous as the one offered by science. But there was a further attraction. The method of science, the insistence upon sensory data as the groundwork of all speculative thought, found in Tennyson a particularly receptive student. A close and acute if not especially systematic observer he had always been. Indeed, his insistence upon factual accuracy drove him to sometimes amusing extremes. But he knew also that sense experience could be indulged in as an end in itself, luxuriant, voluptuous, riotous. His father's sermons back at Somersby had ominously pointed out the dangers of such tendencies;[28] Arthur Hallam likewise had called it "dangerous for frail humanity to linger in the vicinity of the senses";[29] James Spedding, another college friend, found fault in Tennyson's "over-indulgence in the luxuries of the senses,"[30] and Tennyson himself moralized most impressively on the self-same vice in "The Lotos Eaters," confirming all warnings that had been issued to himself.

From this difficulty science offered a way out, for science carried the human capacity for sense perception beyond mere sensory experience and built from sense perception a body of organized knowledge which charmed by its orderliness. Here was a delight far less open to censure, either from oneself or others, and yet here too a danger lurked: the vice of intellectual pride. Again, the men and books of Cambridge enter the picture. Whewell in his *Of a Liberal Education in General* was to grapply directly and by inference with this danger. During Tennyson's years, the need for tempering the pride of the scientist could hardly have been far from Whewell's mind, for he had declared publicly, in the year before Tennyson's coming up, that

> The most capacious intellects of Christian times have found room for the love of knowledge without expelling the love of God. Especially would I point to two names by the common consent of all, the greatest in the records of this modern philosophy; [Newton and Bacon,] the great Conqueror and the great Legislator . . . rebelled not against their Maker.[31]

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[27] *Tennyson: An Introduction and a Selection* (London, 1946).

[28] W. D. Paden, *Tennyson in Egypt*, University of Kansas Humanistic Studies, No. 27 (Lawrence, 1942), p. 21.

[29] Review of Tennyson's *Poems, Chiefly Lyrical*, in *The Englishman's Magazine*, 1831. (Reprinted in *Remains in Verse and Prose* (London, 1863), p. 297.)

[30] *Memoir*, I, 97.

[31] From the first of four sermons delivered in Trinity College Chapel in February, 1827. Todhunter, I, 324.

The younger Herschel had written, with Whewell's warm approbation, that

> Nothing can be more unfounded than the objection which has been taken, *in limine*, by persons well meaning perhaps, certainly narrow-minded, against the study of natural philosophy —that it fosters in its cultivators an undue and overweening self-conceit, that it leads them to doubt the immortality of the soul and to scoff at revealed religion. Its natural effect we may confidently assert on every well-constituted mind is and must be the direct contrary.[32]

Tennyson, with a surer instinct than Herschel's for the various rebellious -isms which were to arise later in the century, accompanied his call for fuller knowledge with another appeal:

> Let knowledge grow from more to more,
> But more of reverence in us dwell. . . .

and again,

> Make knowledge circle with the winds
> But let her herald, Reverence, fly
> Before her to whatever sky.

While yet a student, he reflected the temper prevailing at Cambridge when he wrote

> O God make great this age that we may be
> As giants in thy praise.[33]

One cannot point to Cambridge in the late 1820's as a model of efficiency in the teaching of the natural sciences, but at the same time there is no denying that the university was in process of according those studies the attention they deserved. Tennyson absorbed what he needed from the accumulated body of knowledge in the several departments—enough to place himself somewhere above the rank of dilettante—and more important, he absorbed at Cambridge an attitude, a frame of mind in which science stood as one of the master affirmations of human life. Tennyson had shown a genuine insight into the suicide's psychology when he wrote these stanzas:

> No life that breathes with human breath
> Has ever truly long'd for death.
>
> 'Tis life whereof our nerves are scant
> O, life, not death, for which we pant;
> More life, and fuller, that I want.

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[32] *Discourse,* p. 7.
[33] "To Poesy," *Memoir,* I, 60.

The sciences furnished a potent and, for Tennyson, a necessary answer to this cry. At the same time, the men of Cambridge anticipated and moderated the impulse to exult in the achievements of science. Even the most accomplished scientist was but the darkly-wise detector of causes. The glory of nature belonged not to man, not to science, but to God. Science and religion, "sense and soul," accorded well at Cambridge. In later years Tennyson was to hope that this "one music" could be regained.

THE VEGETATION OF DODGE COUNTY, WISCONSIN 1833–1837

HERBERT E. NEUENSCHWANDER
*University of Wisconsin**

This study of the vegetation of Dodge County was initiated for the purpose of determining the character of the vegetation existing prior to the advent of settlement by the white man.

The land comprising Dodge County lies within the Rock River lowland between the gentle backslope of the Magnesian limestone cuesta and the steep escarpment of the Niagara cuesta. The entire county is overlain with Cary age Wisconsin glacial drift, and the topography is characterized by gently rolling or level land in the central and northwestern part, and drumlins in the east, south and southwest. Elevations above sea level vary from 823 feet at Reeseville in the southwest to 1,044 feet at Knowles in the northeastern part. The streams which figure prominently in the distribution of vegetation are the Wildcat Creek and the Rock, Crawfish, and Beaver Dam Rivers.

The data on the vegetation of 1833 to 1837 were collected by government surveyors. These surveys cover the section lines of each township. On each quarter section corner and on each section corner, witness trees were marked and recorded. In addition, sizable trees along each section line were recorded, and general summaries of the principal trees were given at the end of each line, as well as at the completion of each township. Surveys were generally conducted from June to January, each township requiring about seven to nine days and over a hundred miles of walking. Altogether, a total of 6,246 trees of twenty-five species were recorded and also considerable information about Indian trails and activity. These records were studied in detail by Norman C. Fassett and the writer.

ACKNOWLEDGMENTS

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* Present address: Hustisford, Wisconsin.

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VEGETATION TYPES

Seven types of vegetation have been determined from the interpretation of the surveyors' records of Dodge County dating back to the years between 1834 and 1837. There were prairie, sedge-meadow, oak opening, oak-hickory and maple-basswood. In addition, two kinds of swamp were recognized, the coniferous swamps of tamarack and the hardwood swamps of black ash and elm or willow.

Prairie

Prairie formations, characterized by red root, rosinweed and buffalo grass occupied a considerable portion of the central and northwestern part of the county.

A characteristic description of the prairie lands, on the line between sections 4 and 5 of township 12 north range 13 east, in January of 1835, reads as follows:

at 7.50	a ravine
40.00	set quarter section post and raised a mound
79.18	intersect north boundary at post—land gently rolling first-rate prairie—growth of grass and weeds

Another description of oak woods and prairie was found on the line between sections 10 and 11 of township 13 north range 14 east:

at 10.00[1]	marsh
14.00	left marsh
15.73	Bur oak 24″
40.00	bur oak 8″ S 25° E 79L[2]
	bur oak 28″ N 52° W 106L
42.54	bur oak 12″
46.00	leave timber and enter prairie
80.00	set post and raised a mound of earth and sod. Land first half mile bur and white oak timber. Last half mile first-rate prairie. Growth of grass and weeds.

The distribution of prairie plants coincide rather closely with the level or moderately rolling lands of outwash origin, where marshes were few and streams were small. Most of the prairie was found west of the Rock River having its center around Fox Lake, the greatest part lying between the marsh of the Beaver Dam River on the west and the Horicon marsh on the east.

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[1] These figures indicate the number of chains and links from the section corner beginning at the south end of each line and going north.

[2] The number "8" indicates the diameter of the tree at breast height. This bur oak stood 40 chains north of the corner post, 25° east of south, at a distance of 79 links from the post. One link is 7.92 inches. One mile is 80 chains.

Since it is thought that the prairies of this state were maintained primarily by fire, we have only to note that the center of activity of the Winnebago Indians within the county was at Fox Lake where more than a dozen camps and villages were known to have existed as recently as 1830. Annual fires which overran the prairie were due to various causes such as the driving of game animals, ceremonial torches, Indian battles, signaling and accidental outbreaks arising at camps. Many trails and camp sites of the redmen were associated with prairie areas throughout the county.

Occasionally, a prairie area was found adjacent to a tamarack swamp, as in sections 34 and 35 of township 10 north range 17 east. Although such close proximity rarely occurred, the most logical explanation seems to have been controlled burning by the Indian encampment in section 35.

The largest single prairie areas in Dodge County covered parts of township 13 north range 14 east, 13 north range 13 east, 12 north range 14 east, 12 north range 15 east, and 12 north range 13 east.

Wet or low prairies, though not common, were usually located with respect to the headwaters of some small streams, the most prominent areas being recorded for sections 25, 35, and 36 of township 10 north range 16 east, and in sections 11, 12, 25 and 26 of township 11 north range 14 east. Some areas of wet prairie also existed in the riverbottoms, as in sections 25, 35, 36 and 19 of township 10 north range 13 east, near the Crawfish River. These wet prairies are believed to be due more to the seasonal fluctuations of water than to any permanent cause.

In general, then, the prairie lands of this county were influenced by topography, drainage, and the presence of the Indian inhabitants. The natural firebreak of the Rock River and the Horicon Marsh also did much to discourage the growth of prairie grasses east of that river.

As settlement of the county advanced, some of the prairie gave way to agriculture, and with the cessation of fires, the remainder soon gave way to forest growth. An oak-hickory woods is now occupying a part of section 29 of township 12 north range 15 east, which was once prairie, and similarly, a maple and basswood forest has invaded the prairie in section 25 of township 12 north range 14 east. The examples of succession, however, are few, and most of the original lands are now crop lands.

Marshes or Sedge-Meadow

In the area of marshland, Dodge County has always ranked among the highest in the state and a comparison with the records of the Land Economic Inventory (1939) shows that the county still ranks second in the state with as much as 21% of its land in marsh.

Early surveyors were generally agreed on the use of the term "marsh" and used it with reference to areas having a growth of grass, sedge, and flags. Occasionally, beds of wild rice were noted, particularly on the more sluggish streams adjacent to the marshes. Marsh lands were usually surveyed during late fall and winter to avoid difficulties of travel and in one case, that of Horicon Marsh, final surveys were postponed several times due to the rather high and constant water level.

Marshes were more dependent upon topography than any other existing floral type and their general distribution follows the region of drumlins. The south and west are dotted rather heavily with long narrow stretches of marsh running north and south in low areas between the drumlins, while the east is devoid of marshes for the most part. Some marshes have extensive east and west connections, such as the one in township 10 north range 15 east, which constitutes the drainage system of the Dead Creek.

Both the headwaters of streams and the river bottoms have also contributed to the sedge-meadow areas of the county. The Beaver Dam and Crawfish Rivers once had considerable marsh areas, but the largest single marsh was one above Horicon, at the headwaters of the Rock River. Frequently referred to as the "Grand Marsh", the area above the present city of Horicon comprised more than 30,000 acres and occupied a shallow basin once a glacial lake. This marsh owed its existence to a natural dike or moraine in the vicinity of Horicon, as well as to the clay and gravel bed with which it is underlain.

A. G. Ellis traversing the township 12 north range 15 east on about January 11, 1837, recorded the following information about Horicon Marsh:

North between sections 13 and 14
at 13.50 Rock River SE 75L
33.00 Rock River SW 75L
40.00 set quarter section post in marsh
80.00 set post, corner sections 11, 12, 13 and 14. Land all one uniform marsh—water about three feet deep. January 11, 1837.

North between sections 1 and 2
at 40.00 set quarter section post in marsh
76.90 set post, corner sections 1 and 2 in marsh, no bearings. Land all marsh. The post on this marsh will not, it is believed, be exposed to fire; and being of good size and well planted and marked, may be found for many years.

Further facts concerning the original state of the marsh at Horicon are given by the same surveyor when he ran lines north between sections 4 and 5 and sections 17 and 18 of township 12 north range 16 east:

North between sections 4 and 5
at 40.00 set quarter section post in marsh
78.42 town line 1.13 links west—post set in marsh. Land all marsh. This marsh is nearly a lake 3 to 4 feet deep with high banks bold and well defined. Good land on the border.
North between sections 17 and 18
at 40.00 set quarter section post in marsh
80.00 set corner post in marsh. Land all marsh. The posts on this marsh are large and set deep and it does not appear to be often run over with fire. They may stand for years. January 27, 1837.

Occasionally, sedge-meadows came into existence because of a rock outcrop, as can be seen in township 10 and 11 north of range 16 east. At Hustisford, a three quarter mile of rapids, formed by Richmond shale (rising to the surface 7 feet above the ordinary level of the bed of Rock River) created a marsh well over 2,000 acres in extent.

Other marsh lands of considerable size existed along the course of the Rock River, and a glance at the map will demonstrate the fact that marshes were usually associated with oak openings on low elevations and with oak-hickory forest on the higher elevation west of the Rock River. East of this river, however, marshes were limited to the course of streams which were suitable and were almost non-existent in the absence of streams.

The noticeable absence of sedge-meadows in the rolling topography east of Rock River may have been due to the presence of numerous small fast-flowing streams which resulted in better drainage among the maple forested hills. Better drainage permitted the growth of swamp hardwoods and tamarack between the hills, rather than marsh grasses which require more constant moisture.

As might be expected, many of the former marsh areas have dried up since they were first recorded; some have been drained and still others have become the basins of artificially created lakes. Some evidence of plant succession has been found on marsh areas, although in most places, these areas have remained in substantially the same state that they were in more than a century ago.

In section 15 of township 10 north range 16 east, the former meadow is today cropland, and in section 22 of township 11 north range 16 east, the land is now covered with a growth of tag-alder and dogwood. In section 27 of township 10 north range 16 east, the marsh is today covered with such species of trees as black ash and elm.

Equally interesting is the fact that some areas once a prairie, tamarack or black ash and elm swamp have since become marsh areas by the removal of trees and the damming of streams.

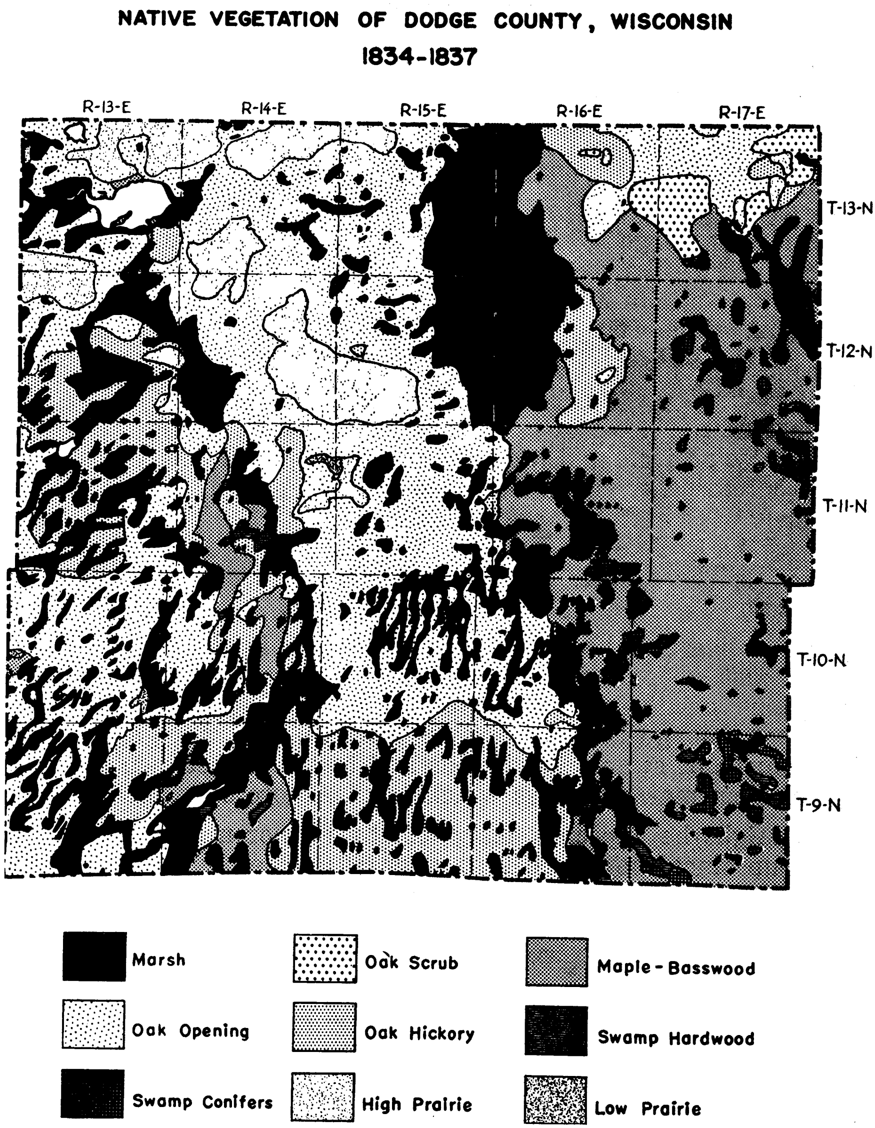
NATIVE VEGETATION OF DODGE COUNTY, WISCONSIN
1834-1837
R-13-E
R-14-E
R-15-E
R-16-E
R-17-E
T-13-N
T-12-N
T-11-N
T-10-N
T-9-N
Marsh
Oak Scrub
Maple-Basswood
Oak Opening
Oak Hickory
Swamp Hardwood
Swamp Conifers
High Prairie
Low Prairie

FIGURE 1.

Oak Openings

If one were to compare the extent of the land once covered by oak openings with other types of vegetation in this county, one would see that it ranks second only to the maple-basswood area. However, except for a small section in the extreme northern part lying east of the Horicon marsh, there was no oak opening area east of the Rock River.

Of the four types of oak openings represented, the bur and black oak openings were most frequent and formed the predominant type in areas closely adjacent to the prairie and, therefore, frequently overrun by fire.

In other areas receiving more protection from fires, another type of oak opening, composed of white and bur oak trees, was found. This type was probably more recent in origin than the bur and black oak opening, and the degree of its invasion of the prairie probably varied with the amount of time between successive prairie fires. Many oak openings were also composed of bur, black and white oak trees and these are thought to be an indication of an invading oak-hickory stage primarily because of the sensitivity of white oaks to fire.

A fourth type of opening consisted of almost pure stands of scattered bur oaks. These trees were perhaps the first to be established as groves on the prairie and were the least sensitive to fire. The open crown and light shade of bur oaks leads one to believe that these trees were not responsible for initiating any changes toward the succession of other trees.

The presence of large bur oak trees within the oak-hickory forest not far distant indicates their ability to coexist in the forest as well as on the prairie. Since many of the individual bur oaks had attained diameters above 30 inches and even up to 40 inches with an estimated age of over 200 years, it is conceivable that they withstood the periodic menace of prairie fires. Their age might also suggest that they outlived oak-hickory stages, remained scattered, and maintained their independence of local vegetation.

From the evidence available in the records of this county, bur oak openings cannot be considered as an intermediate step between the prairie and the oak-hickory forests.

A typical bur oak opening such as the following may have been one reason for the numerous bur oaks (1738) being recorded for this county. This number was twice that of any other species:

North between sections 9 and 10 of township 12 north range 15 east
at 8.05 bur oak 4″
40.00 quarter section corner
bur oak 10″ S 36° E 1.86L
bur oak 10″ N 41° W 0.97L

55.60 bur oak 12″
79.00 enter marsh
80.00 corner to sections 3, 4, 9 and 10
bur oak 12″ S 28° W 2.64L
no other near
Land rolling second-rate bur oak openings.

To illustrate other types of oak openings, the following may be quoted:

North between sections 35 and 36 of township 13 north range 14 east
at 4.92 bur oak 10″
34.74 white oak 14″
40.00 quarter section corner
bur oak 12″ S 32° W 20L marked
bur oak 12″ N 80° E 5L marked
61.70 white oak 15″
64.40 creek 50L and enter marsh
80.00 corner to sections 25, 26, 35 and 36
bur oak 18″ S 86° E 7.75
bur oak 17″ N 8° E 12.68
Land level second rate with bur and white oak timber. Undergrowth of grass and weeds.

North between sections 32 and 33 of township 10 north range 16 east
at 17.50 sluggish stream 12C
40.00 quarter section corner
bur oak 9″ N 71 W 3.06
bur oak 8″ S 57½ W 2.17
49.64 trail S W
62.64 black oak 14″
80.00 corner to sections 28, 29, 32 and 33
black oak 10″ S 76° E 41
bur oak 8″ N 63° W 68
Land level second rate. Bur, black and white openings, red root and rosinweed.

From the above illustration and those that follow, it may be seen that the undergrowth of the oak openings throughout the county consisted either of prairie plants or "grass and weeds".

Bur and black oak openings existed in sections 27 and 28 of township 13 north range 14 east and were further characterized as follows:

North between sections 27 and 28
at 30.00 left prairie
40.00 quarter section corner
bur oak 12″ N 64° W 1.31
bur oak 14″ N 17° E 1.81
49.08 bur oak 27″
59.52 bur oak 24″
79.78 black oak 14″

80.00 corner to sections 21, 22, 27 and 28
black oak 18″ N 77° E 70
black oak 19″ S 65° E 58
black oak 14″ S 32° W 85 marked
black oak 12″ S 17° W 79 marked
Land level first rate with bur and black oak timber. Undergrowth of hazel, grass and weeds.

By noting the location of the above described oak openings, it may be seen that each area was in all probability traversed by wind and fire and that each combination was dominated by the larger and older bur oak trees. From the remarks concerning the type of undergrowth and those indicating the tree diameter, it may be inferred that the bur oak openings were maintained by fire, while the other types of oak opening were probably destroyed occasionally by such fires.

Some workers have advanced the idea that the distribution of the oak openings in the 1830's indicates an area which was once a prairie when the climate was warm and dry, and that the bur oaks, as well as the other oak trees, have only recently come in. Such a contention seems quite plausible, but it is now believed that the Indian population which annually set fire to the prairie grasses was a factor in maintaining the oak opening.

Many of the virgin trees of Dodge County today are bur oaks and white oaks, remnants of former oak openings. A typical oak opening is becoming increasingly hard to find today, but some permanent pastures and golf courses still reveal their former character. Permanent pastures having oak trees of a diameter of 12 to 18 inches are usually located in the heart of the original oak opening areas; examples may be found today in sections 27 and 34 of township 12 north range 15 east.

As in the case of the prairie and the marshes, there are also some evidences of floral succession during the last century. In section 21 of township 12 north range 14 east, oak and hickory have replaced the oak opening, while in section 29 of township 10 north range 15 east, the maple and basswood forest now predominates what was once oak opening. Many similar examples could be cited throughout the county.

Oak-Hickory Forest

The major oak and hickory forests of the county occupied the areas between the larger rivers and were concentrated mainly in five townships along the southern boundary.

Interpretations of oak forest were based upon the presence of the following species and their associated undergrowth; bur, black and white oak, cherry, elm, aspen and hickory with undergrowth composed of hazel, white oak, aspen, briars and vines.

More specifically, typical oak woods were described as follows by the early surveyors:

On the line between sections 35 and 36 of township 12 north range 13 east

at 8.09	black oak 14″
15.98	black oak 18″
21.64	aspen 24″
25.50	black oak 18″
39.25	aspen 18″
40.00	quarter section corner
	hickory 12″ S 37° W 10
	hickory 10″ N 45° W 23
48.00	hickory 10″
58.00	aspen 18″
63.95	black oak 14″
73.38	aspen 18″
77.90	aspen 18″
80.00	corner to sections 25, 26, 35 and 36
	aspen 14″ S 14° W 48
	black oak 18″ S 53° E 33
	black oak 18″ N 31° E 27 marked
	black oak 40″ N 64° W 28 marked
	Land level second rate with bur and black oak, aspen and hickory. Undergrowth hazel, aspen and white oak.

On the line between sections 32 and 33 of township 12 north range 13 east

at 7.70	white oak 18″
11.64	bur oak 24″
27.00	white oak 14″
39.34	elm 18″
40.00	quarter section corner
	elm 24″ S 68° W 10 marked
	elm 14″ N 86° E 37 marked
49.68	white oak 18″
51.35	bur oak 28″
69.32	bur oak 18″
77.62	black oak 14″
80.00	corner to sections 28, 29, 32 and 33
	red oak 14″ S 75° E 47
	bur oak 14″ S 60° W 44
	bur oak 18″ N 33° E 49
	bur oak 18″ N 65° W 13
	Land level second rate with bur, red and white oak, elm, aspen. Undergrowth of aspen, hazel, white oak, briars and vines.

Not all of the interpretations drawn from the records were as clear cut as those above and there were many instances where transitional states existed. To illustrate the difficulty of accurately determining some of the descriptions, we may cite the following two examples:

North between sections 3 and 4 of township 10 north range 14 east

at 21.78	bur oak 14″
40.00	quarter section corner
	lynn 10″
55.21	lynn 10″

77.46	lynn 18″ S 2° W 42
	ironwood 10″ S 72° E 46
	Land rolling second rate. White, black and bur oak, lynn, elm, ash, ironwood and white walnut. September 9, 1836.

North between sections 32 and 33 of township 11 north range 14 east

at 16.68	white oak 24″
21.18	elm 14″
24.12	lynn 18″
37.08	white oak 12″
40.00	quarter section corner
	lynn 14″ S 79° W 16
	red oak 18″ S 72° E 16
51.38	elm 14″
58.60	elm 18″
63.86	cherry 10″
76.52	bur oak 36″
80.00	corner to sections
	lynn 14″ N 86° E 36
	iron 10″ S 31° E 39
	cherry 14″ S 66° W 16 marked
	iron 18″ N 78° W 14 marked
	Land level first rate timber; all varieties of oak, hickory, elm, aspen, lynn, cherry and walnut.

The foregoing illustrates that the area is still in the oak-hickory stage, but that the maples and basswoods are invading and will soon become the dominating species.

Several transitional lines are shown on the map, and the boundary interpretations cannot be too strict. Such transitions exist between the oak-hickory forests and the maple-basswood forests and are also found where the oak openings approach the oak-hickory forest.

In regard to the pattern of distribution of the oak-hickory forest, several interesting things may be noted. The midwest and southern distribution follows very closely the course of the Beaver Dam and Crawfish Rivers and is more generally determined by the degree of protection from fire which was afforded by the wet marshes. In many areas, the oaks and hickories encroached upon the grasses and the bur oaks of the oak openings only when the local fires ceased to occur.

Although oak forests formerly occupied less than one third of the area of the county, they are today found scattered throughout, but contrary to what one might expect they are still less extensive than the maples and basswoods.

Numerous examples throughout the records of vegetation have shown the existence of oak woods which presumably invaded the prairie or perhaps succeeded a black or white oak opening. Such areas were nearly devoid of large bur oaks, and in some cases, had no bur oak at all. This corroborates an earlier view that bur oaks or bur oak openings are not essential in successional stages from the prairie to oak woods. It further illustrates the chance factor by which certain species of oaks invade and become established when suitable conditions obtain.

As previously mentioned, oak forests were most extensive on the west side of Rock River, but there were also several minor areas east of the river. One in particular, lying between the Horicon marsh on the west and the Rock River on the north and east and otherwise surrounded by maple basswood forests, had all the characteristics of an oak forest, and was undoubtedly due to the Indian habitation, judging from the great number of mounds and several villages known to have been located in the same region.

Other evidences of oak woods were found in townships 13 north range 16 east and 13 north range 17 east. The type of oak woods indicated can best be referred to as "scrub oak" and was located on the boundary between the oak openings of the north and the maple and basswood forest of the south. A summary of township 13 north range 17 east, in June, 1836, read as follows:

"Northern part of township is high dry land with thin soil. A strip extending across the township 2 to 3 miles wide is covered with a "thicket" of hazel, plum, thorn, aspen and no timber it having been destroyed by wind and fire."

Another brief description of the area may be had (from the line between sections 19 and 20 of township 13 north range 17 east) from the pen of A. G. Ellis:

North between sections 19 and 20
at 8.13 white oak 20″
23.50 spring brook 10L; the spring is about 50L. west of the line, has pure cold water and a limestone bottom.
40.00 quarter section corner
aspen 3″ N 39° W 31
cherry 3″ N 60° 30′ E 38
57.35 white oak 30″
80.00 corner to sections 17, 18, 19 and 20
aspen 3″ N 57° 30′ W 16
aspen 3″ N 34° 30′ E 27
Land second rate, level, thinly timbered white and black oak, aspen. Whole mile a thicket of thorn, hazel, aspen, plum, and prickly ash.

These descriptions are representative of the "thickets" lying between the large Indian encampments on the west and the main Lake Winnebago to Milwaukee trail on the east. The presence of thorn, evidentally referring to hawthorne, is due to the limestone soils of the Niagara escarpment, and the aspen was due to fire. The occurrence of oak forests east of Rock River can thus be seen to have their origin as well as their maintenance due to Indian occupation and annual fires. The nature of the undergrowth in the oak-hickory association, as well as in other associations, was considered essential to the interpretation of all types of vegetation throughout this study. Of particular interest, was the presence of prickly ash together with hazel, oak and vines. Prickly ash has frequently been thought of as a sign of disturbance, but its universal presence in

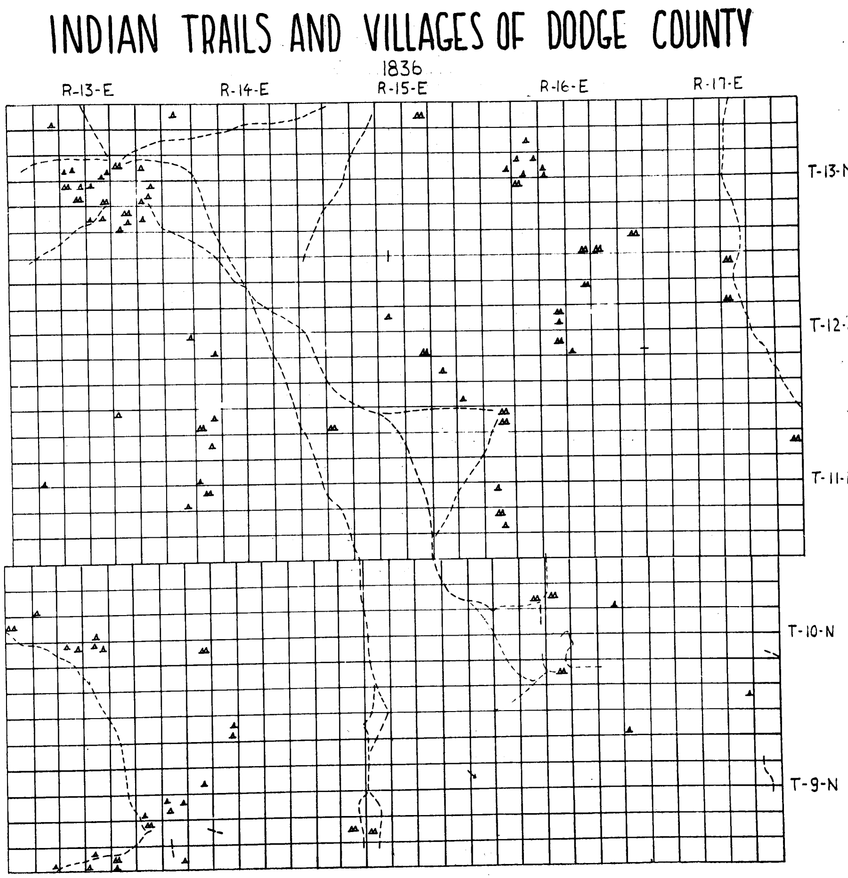

FIGURE 2.

oak forests and throughout the transition stages between the oak forest and the most mature maple-basswood forests, may well indicate that its occurrence is a natural one and not due to a disturbance.

In general, the oak-hickory forests of a hundred years ago have now increased their range on the west side of Rock River, but are found only in former oak opening or oak forest areas on the east side of that river. Along with extension of range, there has been a replacement of oak openings by oak woods. A considerable portion of the original oak woods has remained unchanged while still other oak woods have been replaced completely by the succession of maple and basswood.

Maple-basswood

Maple-basswood is considered to be the climax forest type in this state, and the Rock River is essentially the western boundary of the most extensive maple forests in the southeastern counties. There is, however, some indication that this forest east of the river comprised a belt of about 8 to 10 miles wide and, therefore, should not be considered as stretching all the way eastward to Lake Michigan. This formation as found west of the river comprised only a few small areas. Maple-basswood made up about one third of the total area of the county.

Descriptions taken from a summary of one township reveal the characteristic composition of a maple forest as follows:

> Township 8 north range 17 east
> "The soil is yellowish clay and black or ashy loam. Oak, sugar, lynn, ash, elm, ironwood, white and black walnut. Tamarack. The township is covered with small brush and undergrowth of prickly ash, hazel, oak, thorn, plum and vines. Prairies are small and second rate of prairie grass and rose willow." (June 1836.)

More specific are descriptions of various other section lines. A mature maple-basswood forest devoid of undergrowth was described for the line between sections 11 and 12 of township 9 north range 16 east:

North between sections 11 and 12
at 36.00 leave marsh
40.00 quarter section corner
sugar 12″ N 64° W 11L
sugar 8″ S 86° 30′ E 15L
48.48 elm 18″
64.65 white walnut 14″
80.00 corner to sections 1, 2, 11 and 12
sugar 10″ S 15° E 33L
sugar 12″ N 33° 30′ E 24L
Land except marsh rolling second rate. White oak, black oak, lynn, ash, elm, ironwood and white walnut. No undergrowth.

Another description reads as follows:

North between sections 9 and 10 of township 10 north range 17 east
at 12.50 stream 4C
15.51 white oak 12″
29.33 sugar 11″
40.00 quarter section corner
beech 12″ S 16° 30′ W 34
beech 11″ S 67° E 36

55.34 white walnut 10″
70.86 sugar 14″
80.00 corner to sections
white ash 9″ S 63° E 30
sugar 10″ S 88° W 15
Land rolling second rate. White and black oak, lynn, sugar, ash, beech, iron, elm, and white walnut. Undergrowth prickly ash, oak and ironwood.

Maple-basswood forest similar to those just described covered most of the land in the eastern part of the county east of the Rock River and was conspicuously absent from the lands west of the river, except in portions of townships 9 north range 14 east, 10 north range 14 east, and 11 north range 14 east, all of which lie in the valley of the Beaver Dam and Crawfish Rivers.

The limited distribution of maple-basswood west of the Rock River is again related to the lack of protection from prairie fires, and only occasionally did a forest of this type become established west of a river, as was the case in township 9 north range 14 east near the junction of the two main rivers. It is readily apparent from the map that considerably more protection from fire was required for the establishment of maple forests than was necessary for oak forests. In the eastern part of the county, the success of the maple and basswoods was due to the great expanse of the Horicon marsh, as well as the uniformly effective fire-break afforded by the Rock River all the way south to the southern boundary line of the county. Furthermore, when a comparison of tree diameters was made of all townships having a range of 16 and 17 east within the county, it seemed that the most abrupt and consistent increase in size of such species as white oak, black oak, sugar maple and lynn, occurred in township 10 north. This increase in diameter, which proceeded northward from the southern boundary of Dodge County, suggests that the transition line between the late stages of oak-hickory or early stages of maple-basswood, and the more mature maple-basswoods was also best illustrated in township 10 north. For all purposes then, it may be said that though the maple-basswood forest predominated the lands east of Rock River, it was in its earliest stage of development in township 9 north 17 east, and in its latest stage in 13 north 17 east.

As far as can be determined from the information available, the maple forests were little affected by the Indian occupation of the lands and the establishment of this climax stage was rather the result of the passing of time and of its development east of Rock River.

The climax forest has also exhibited the transitional state wherever oak openings and oak woods were found immediately adjacent, and there is considerable gradation in these areas along the Beaver Dam and Crawfish Rivers.

In one respect, the maple-basswood forest differs from the other vegetation types of this county and that is in the matter of plant successions. Maple forests as a type usually continue indefinitely to succeed themselves unless disturbed. This ability to continue indefinitely has probably been the main factor in the uniformity shown throughout the entire area east of Rock River. As far as succession is concerned, this vegetation type is just the same today as it was a century ago in most of its former range except, perhaps, where lumbering or agriculture has reduced its dominance.

West of the Rock River, the maple forest today equals and will probably soon exceed the oak and hickory forests, due more to the phenomenon of succession than any other single factor. The maples and basswoods have been remarkably successful in invading much of the original oak forest and oak openings and some of the prairies and have thus extended their range on this side of the river.

Tamarack Swamps

Tamarack swamps covered the smallest land area of any vegetation type in the 1830's. The general picture of these swamps was one of a succession to black ash and elm, although nearly pure stands were also recorded.

For a description of a tamarack existing in June, 1836, we may refer to the record from the pen of John A. Brink:

North between sections 10 and 11 of township 9 north range 17 east

at 9.09	ironwood 9″
12.00	enter tamarack swamp
30.72	tamarack 8″
40.00	quarter section corner tamarack 10″ N 88° W 12 tamarack 8″ S 80° E 12
53.12	tamarack 10″
63.50	leave tamarack swamp
73.66	black oak 9″
74.50	enter tamarack swamp
79.50	leave tamarack swamp
80.00	corner to sections 2, 3, 10 and 11 ironwood 9″ N 9° E .09 bur oak 11″ S 65° E .09 Land except swamp rolling second rate white and black oak, sugar, elm, lynn, ash, cherry, ironwood and tamarack. Undergrowth of prickly ash, oak, hazel, alder, vines.

Another description from the handbook of A. G. Ellis reads as follows:

North between sections 21 and 22 of township 12 north range 17 east
at 20.79 tamarack 15″
40.00 quarter section corner
tamarack 14″ S 20° E 18
tamarck 3″ N 61° W .09
66.00 leave swamp
68.30 elm 12″
80.00 corner to sections 15, 16, 21 and 22
lynn 24″ N 53° W 39
elm 12″ S 61° 30′ E 41
Land first 66 chains tamarack and black ash swamp. Remainder first rate lynn, sugar, elm, ironwood, white and black oak.

Since coniferous swamps are near the southern limit of their range in Dodge County, it is not surprising that they were not extensive and that their largest concentration was confined to only three townships. These townships in order of acreage of tamarack swamp were: 9 north range 17 east, 11 north range 16 east and 12 north range 17 east.

The western half of the county had practically no tamarack swamps, the possibility of their existence having been eliminated by recurrent prairie fires. In three isolated locations, however, islands of tamarack surrounded by marsh or oak forests existed. These islands occurred in townships 9 north range 13 east, 11 north range 13 east and 12 north range 13 east.

The growth of tamarack swamps among the maple-basswood forests on the east side of Rock River depended upon the existence of rather low and wet marshy places, and tamarack trees frequently grew in these marshy areas or adjacent to them. Occasionally, the swamps were associated with a stream or its headwater tributaries, as in the case of the Wildcat Creek in township 11 north range 16 east, and the Rubicon River in township 10 north range 16 east. These tamarack swamps are only the remnants of a former more extensive growth of conifers in southern Wisconsin. Only a few scattered trees having diameters of over 16 inches, however, were recorded and it may be assumed that these swamps existed for over 200 years before the time of the survey.

Of all the vegetation types discussed in this paper, the prairie has most nearly become extinct, and second only to the prairie has been the reduction of tamarack. In its original range, there are now many evidences of disturbance or succession although in some areas, an almost pure stand still exists today. Agriculture, drought, and disease have worked together to encourage the growth of alder, dogwood and willow, or black ash and elm where tamarack once stood. In addition, some areas are now mainly marsh while still others have been invaded by maples and basswoods. At the present rate of destruction by drainage and grazing, it seems very probable that tamarack trees will have made their last stand long before the turn of another century.

Black Ash and Elm Swamps

The last type of vegetation to be considered in the history of the flora of this county is another swamp formation composed of black ash and elm.

Long before the early surveyors traversed these lands, tamarack swamps undoubtedly covered much of what was recorded as black ash and elm in the 1830's. The ash and elm swamps are generally considered as an advanced stage of succession in a wooded swamp.

An example of the kind of swamp under discussion may be had from a description of the line between sections 1 and 2 of township 12 north range 17 east:

North between sections 1 and 2
at .50 a river 50L
5.00 bend of river
7.00 leave bend of river
26.60 black ash 12″
40.00 quarter section corner
black ash 14″ S 14° E 15
maple 15″ N 4° 30′ E 36
60.90 black ash 14″
75.77 river 50L
78.38 town line 44L west of post—set post to corner of sections 1 and 2
Land all swamp. Black ash and elm, maple, willow, alder. June 28, 1836.

A similar account was given for the line between sections 16 and 17 of township 11 north range 16 east:

at 18.73 sugar 14″
39.00 enter swamp
40.00 quarter section corner
elm 12″ N 58° W 18
black ash 10″ N 74° E 37
71.50 leave swamp
80.00 corner to sections 8, 9, 16 and 17
aspen 12″ S 69° W 87
white oak 12″ N 64° W 1.26
Land first half mile first rate sugar lynn, oak and ironwood. North one half a black ash and alder swamp.

These swamps were usually associated with streams and marshes and were found with or in close proximity to the tamarack trees, and in almost every instance, the location of these swamp hardwoods on low ground coincided with the distribution of maple and basswood forests on the neighboring high ground.

As was the case with tamarack swamps, the distribution of ash and elm swamps rarely occurred in the western part of the county west of Rock River. Only two townships, 9 north range 14 east and 11 north range 14 east, had any significant areas of swamp. Eastern Dodge County, however, with its abundance of sugar maple forests had considerable areas of ash and elm within four townships, among which were the following: 9 north range 17 east, 10 north range 16 east, 11 north range 16 east and 12 north range 17 east.

Perhaps the greatest factor limiting a broader range of hardwood swamp was the degree of moisture of many of the existing marshes. Only when a marsh was fairly dry and well-drained could a hardwood swamp become established. True transitional areas, so characteristic of oak and maple forests, were practically nonexistent in this type of swamp.

Comparisons of the former range of hardwood swamps with recent vegetation maps of the Land Economic Inventory (1939) show that many of the swamps of a century ago are essentially the same today. In some instances the maple-basswood climax has succeeded them, while in the majority of cases, swamp hardwoods have actually invaded dry marshes. Though these swamps have suffered a slight reduction in some areas, they have actually extended their range in many parts of the county.

Source of Data

The exterior lines forming the boundaries of the townships were surveyed by the following deputy surveyors in the following years:

Between townships	*Range*	*Surveyor*	*Date*
8 & 9 North	13 East	John A. Brink	March, 1835
8 & 9 "	14 "	"	March, 1835
8 & 9 "	15 "	"	March, 1835
8 & 9 "	16 "	"	Feb. 6, 1836
8 & 9 "	17 "	"	Feb. 5, 1836
9 & 10 "	13 "	"	March, 1835
9 & 10 "	14 "	"	March, 1835
9 & 10 "	15 "	"	March, 1835
9 & 10 "	16 "	"	March 25, 1835
9 & 10 "	17 "	John Mullet	Feb. 16, 1836
10 & 11 "	13 "	"	May 20, 1834
10 & 11 "	14 "	"	May 19, 1834
10 & 11 "	15 "	"	May 19, 1834
10 & 11 "	16 "	"	May 17 & 18, 1834
10 & 11 "	17 "	"	May 17, 1834
11 & 12 "	13 "	"	May 30, 1834
11 & 12 "	14 "	"	May 30, 1834

Between townships		*Range*		*Surveyor*	*Date*
11 & 12	"	15	"	"	May 30, 1834
11 & 12	"	16	"	John A. Brink	Feb. 10, 1836
11 & 12	"	17	"	"	Feb. 9, 1836
12 & 13	"	13	"	John Mullet	June 6, 1834
12 & 13	"	14	"	"	June 5, 1834
12 & 13	"	15	"	John A. Brink	Feb., 1836
12 & 13	"	16	"	"	Feb., 1836
12 & 13	"	17	"	"	Feb., 1836
13 & 14	"	13	"	John Mullet	June 16, 1834
13 & 14	"	14	"	"	June 16, 1834
13 & 14	"	15	"	John A. Brink	Feb., 1836
13 & 14	"	16	"	"	Feb., 1836
13 & 14	"	17	"	H. Burnham	June 1, 1835

Township		*Between ranges*		*Surveyor*	*Date*
9	North	12 & 13	East	John Mullet	Nov. 9, 1833
9	"	13 & 14	"	John A. Brink	March 14, 1835
9	"	14 & 15	"	"	March, 1835
9	"	15 & 16	"	"	March, 1835
9	"	16 & 17	"	John Mullet	Feb. 7, 1836
9	"	17 & 18	"	"	Feb. 7, 1836
10	"	12 & 13	"	"	Nov. 11, 1833
10	"	13 & 14	"	John A. Brink	March 14, 1835
10	"	14 & 15	"	"	March, 1835
10	"	15 & 16	"	"	March 25, 1835
10	"	16 & 17	"	"	March 25, 1835
10	"	17 & 18	"	John Mullet	Feb. 17, 1836
11	"	12 & 13	"	"	May 25, 1834
11	"	13 & 14	"	Mullet & Brink	May 26, 1834
11	"	14 & 15	"	John Mullet	May 26, 1834
11	"	15 & 16	"	"	May 27, 1834
11	"	16 & 17	"	John A. Brink	Feb. 7, 1836
11	"	17 & 18	"	H. Burnham	July 16, 1835
12	"	12 & 13	"	John Mullet	June 1, 1834
12	"	13 & 14	"	Mullet & Brink	June 2, 1834
12	"	14 & 15	"	John Mullet	June 4, 1834
12	"	15 & 16	"	John A. Brink	Feb., 1836
12	"	16 & 17	"	"	Feb., 1836
12	"	17 & 18	"	H. Burnham	July 17, 1835
13	"	12 & 13	"	John Mullet	June 11, 1834
13	"	13 & 14	"	Mullet & Brink	June 11, 1834
13	"	14 & 15	"	John Mullet	June 12, 1834
13	"	15 & 16	"	John A. Brink	Feb., 1836
13	"	16 & 17	"	"	Feb., 1836
13	"	17 & 18	"	H. Burnham	July 18, 1835

The surveyors and dates of survey of the interior lines which bound the 36 sections within each township were:

Township		*Range*		*Surveyor*	*Date*
9	North	13	East	John A. Brink	Sept. 24 to Oct. 2, 1836
9	"	14	"	"	Aug. 28 to Sept. 5, 1836
9	"	15	"	"	Aug. 18 to 27, 1836

Township		*Range*		*Surveyor*	*Date*
9	"	16	"	"	July 12 to 27, 1836
9	"	17	"	"	June 5 to 14, 1836
10	"	13	"	"	Sept. 15 to 22, 1836
10	"	14	"	"	Sept. 6 to 13, 1836
10	"	15	"	"	Aug. 7 to 16, 1836
10	"	16	"	"	July 1 to Aug. 2, 1836
10	"	17	"	"	June 16 to 29, 1836
11	"	13	"	G. W. Harrison	Jan. 25 to 31, 1835
11	"	14	"	"	Jan. 15 to 23, 1835
11	"	15	"	"	Dec. 17 to 24, 1834
11	"	16	"	A. G. Ellis	July 27, 1836
11	"	17	"	"	July 15 to 23, 1836
12	"	13	"	G. W. Harrison	Jan. 8 to 15, 1835
12	"	14	"	"	Jan. 1 to 7, 1835
12	"	15	"	A. G. Ellis	Jan. 11 to 18, 1837
12	"	16	"	"	July 8 to 13, 1836
12	"	16	"	"	Jan. 25 to 28, 1837
12	"	17	"	"	June 27 to July 7, 1836
13	"	13	"	G. W. Harrison	Dec. 3 to 16, 1834
13	"	14	"	"	Nov. 27 to Dec. 3, 1834
13	"	15	"	A. G. Ellis	Jan. 2 to 9, 1837
13	"	16	"	"	June 20 to 25, 1836 Dec. 28 to 31, 1836
13	"	17	"	"	June 8 to 18, 1836

Names of Trees Used in the Surveyors' Records

Alder (Speckled Alder)	Alnus rugosa
Aspen	Populus sp.
Beech	Fagus grandifolia
Black Ash	Fraxinus nigra
Black Oak	Quercus ellopsoidalis
Bur Oak	Quercus macrocarpa
Black Walnut	Juglans nigra
Briars	Rubus sp.
Buffalo Grass	Bouteloua hirsuta
Cherry (Black)	Prunus serotina
Cherry (Red)	Prunus pensylvanica
Elm (American)	Ulmus americana
Flags	Iris sp.
Hazel (Hazelnut)	Corylus americana
Hickory	Carya sp.
Ironwood	Ostrya virginiana
Lynn (Basswood)	Tilia americana
Maple (Red)	Acer rubrum
Plum	Prunus americana
Prickly Ash	Zanthoxylum americanum
Red Elm	Ulmus fulva
Red Oak	Quercus rubra

Red Root	Ceanothus americanus
Rose Willow	Cornus stolonifera
Rosinweed (Compass Plant)	Silphium laciniatum
Sedge	Carex sp.
Sugar (Sugar Maple)	Acer saccharum
Tamarack	Larix laricina
Thorn (Hawthorne)	Crataegus sp.
White Ash	Fraxinus americana
White Oak	Quercus alba
White Walnut (Butternut)	Juglans cinerea
Wild Rice	Zizania aquatica

DIAPAUSE, AND THE EMBRYO OF THE SARATOGA SPITTLEBUG

RONALD L. GIESE
Department of Entomology, University of Wisconsin

and

LOUIS WILSON
Department of Biology, Marquette University

The Saratoga spittlebug, *Aphrophora saratogensis* (Fitch), has been an economically important forest insect pest for over fifteen years. It is widely distributed throughout the Lake States where it often causes severe damage and mortality to young red and jack pines (Benjamin, *et al*, 1953). Although the biology has been worked on extensively, (Anderson, 1945 and Secrest, 1944), little information is available concerning the embryonic stage. To obtain a better understanding of the pest, and the environmental factors influencing its embryonic development, an investigation of the egg stage was conducted.

EGG

Eggs of the Saratoga spittlebug are laid in late August and September. Each female is capable of ovipositing as many as 27 eggs (Anderson, 1947). The deposition site is primarily between the bud scales on terminal and lateral buds of red pine. Eggs are laid either singly or in rows of from two to eight. As many as 145 eggs have been observed in the confines of a single terminal bud. The eggs are ellipsoid with a slightly curving tip, and are less than 2 mm. in length. The exochorion is transparent and united to the endochorion by minute hairs. The endochorion contains a yellow pigment which often changes to grey or blue.

DIAPAUSE

An obligatory quiescent stage, diapause, is experienced by the embryo of the Saratoga spittlebug in late fall. The average length of the embryos in diapause is .649 mm. $\pm$ .025 S.D. In the diapausing state, rudiments of legs and mouthparts are apparent, and a red spot, which is contiguous to the abdominal dorsum in the caudal region, can be seen.

Eggs collected shortly after oviposition were divided into two groups. Group I, containing 100 eggs, was incubated at 80°F. No eggs in this group differentiated beyond the diapausing stage, and after two years exposure appear viable.

Eggs in group II, also 100 in number, were subjected to 20°F for 60 days. Nine first instar nymphs hatched in a minimum period of 23 days, when reared at 79% humidity and 80°F. The remainder differentiated well beyond the diapausing stage and probably would have hatched, had fungi not inhibited their development.

Diapause Termination

Diapause research has revealed that environmental factors other than temperature are often instrumental in the initiation and termination of diapause. Light and various chemicals may also be involved. Slifer (1948) showed that diapause could be broken in grasshopper eggs by exposing them to xylol.

In preliminary studies, diapausing spittlebug eggs were exposed to a number of chemicals.

Xylol—this application followed Slifers' method.

Mascerated Red Pine Needles—fresh needles were mascerated in a food blender and the solution autoclaved. Filter paper was saturated with the solution and eggs placed on it. The paper was then inserted into a sterile petri dish.

Mascerated White Pine Needles—same as above.

Control—paper was saturated with distilled water.

The eggs used in these studies had not been exposed to freezing temperatures; all were sterilized with a dilute solution of sodium hypochlorite. The groups were held at parallel conditions of temperature and humidity.

After five days, it appeared that diapause had been terminated in only one of these groups (Table 1). Eggs subjected to the mascerated red pine needle solution contained embryos which exceeded substantially in length, the *index* (average length of diapausing embryos).

TABLE 1

EFFECT OF CHEMICALS ON DIAPAUSE

Chemical	*No. reps*	*Length of embryos @ 5 days*
Xylol	10	.635 mm. ± .032 S.D.
White Pine Needle Solution	10	.646 mm. ± .015 S.D.
Red Pine Needle Solution	10	.961 mm. ± .023 S.D.
Control	10	.636 mm. ± .036 S.D.

These studies suggest the possibility that chemicals present at the site of deposition may, in addition to temperature, be involved in the termination of diapause. It should be pointed out that cold-shock is most likely the *normal* initiator of diapause release. Secondly, chemicals which aid in the termination of diapause may ultimately determine in part, the preference or embryo survival for one host in comparison with another.

Red Spot

It was previously stated that a red spot is found in the spittlebug egg. It is probable that the "spot" is typical of this species since in 1250 eggs examined, the spot occurred in over 99%. It was assumed that the remaining eggs, that lacked the spot, were either non-viable or dead. The "spot" makes its appearance shortly after deposition of the egg. None of the eggs dissected from 13 adult female spittlebugs contained the red spot, even though the embryos had developed to *index* length while still within the parent spittlebug.

The spot is spherical and occupies a diameter of about one fourth the length of the diapausing embryo. After diapause termination and the development of the embryo continues, the red spot decreases in diameter progressively, until by the twelfth day it has disappeared (Fig. 1).

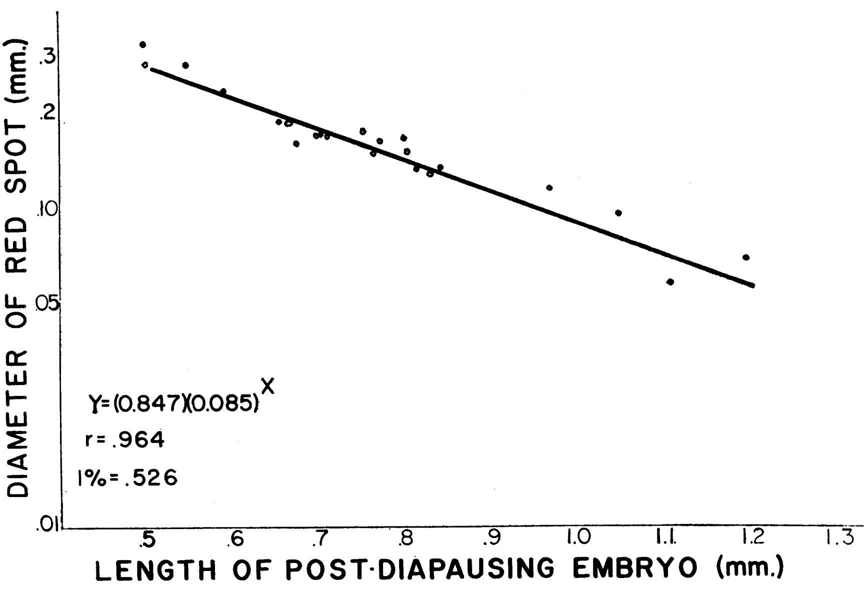

Figure 1. Relation of the red spot to the developing embryo.

The function of this structure is unknown. One idea forwarded by researchers is that the "spot" is the source of pigment, from which the abdominal region of the first four instar nymphs derive their red coloration. Another theory forwarded by the author is that the red structure is a mycetome, an organ containing symbiotic micro-organisms, sometimes found in association with the embryos of certain sucking insects.

No concrete evidence has been found to support either hypothesis. Further investigations should show the function of the "red spot" and explain its relation to the development of the embryo.

SUMMARY

Eggs of the Saratoga spittlebug are oviposited in abundance in bud scales of red pine either singly or in rows of from 2 to 8. As many as 145 eggs may be deposited in a single bud. The diapausing mechanism is present in the life history of this species. The embryo in this stage averages .649 mm. ± .025 in length. Chemicals at the deposition site may be instrumental in diapause termination. A red structure, contiguous to and typical of the embryo is found over 99% of the time. This structure decreases in diameter with progressive development of the embryo.

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APPENDIX

Aphrophora saratogensis Egg Serial Section Technique

The pointed tip is cut off of the fresh egg. This allows penetration of the solutions.

Fixation

The eggs are fixed in Petrunkavitch's Soln. #2 for 48 hours or longer.

Dehydration

Eggs into:

35% ethyl alcohol for 24 hours
50% ethyl alcohol for 24 hours
70% ethyl alcohol for 24 hours
85% ethyl alcohol for 24 hours

95% ethyl alcohol for 2 hours
100% ethyl alcohol for 1 hour
fresh 100% ethyl alcohol for 1 hour
100% ethyl alcohol and chloroform (1:1) for 24 hr.
100% chloroform for 24 hours
Chloroform and tissuemat (60–62°C melting pt.) (1:1) for 24 hours. Place in oven.
Pure tissuemat—3 changes for 24 hours each.
Imbed in paraffin blocks.
Microtome sections 4–5mu into serial ribbons.
Mount serial sections on slides using Mayer's albumen as an adhesive.

Staining

Place slides with sections into:

I pure xylol for 2 min. (removes tissuemat)
II pure xylol for 2 min. (removes contamination)
I 95% ethyl alcohol for 2 min.
II 95% ethyl alcohol for 2 min.
85% ethyl alcohol for 2 min.
70% ethyl alcohol for 2 min.
50% ethyl alcohol for 2 min.
35% ethyl alcohol for 2 min.
Wash in water for 1 min.
Aqueous stain—Delafield's or Harris' haematoxylin for 10 min.
Rinse in water.
Rinse in 70% ethyl alcohol for 1 min.
Rinse in 95% ethyl alcohol for ½ min.
Stain with eosin for 5–10 seconds.
Rinse 4 times with 100% ethyl alcohol continuously running over slide.
Repeat with xylol.
Drain xylol and add drop of clarite.
Place coverslip and label.

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A STUDY OF THE MALE GENITALIA OF THE MELANOSTOMINI (DIPTERA-SYRPHIDAE)

C. L. FLUKE
University of Wisconsin

There have been very few published studies on the male genitalia of the genera belong to the *Melanostomini,* due probably to the rather minute size of these structures. Metcalf[1] in his contribution of 1921 describes the "bicornuate" form of the styles of *Platycheirus* which he claimed to be characteristic of the genus but made no note of the same type of styles found on certain species of *Melanostoma* now mostly assigned to *Carposcalis,* nor of the strongly curved sickle-shaped superior lobes which appear to be even more characteristic of *Platycheirus* than the forked styles.

The methods followed are essentially those described by me in 1950[2] for the *Syrphini.* For consistency in my work I am retaining most of the same definitions but would call attention to the excellent works of Stuckenberg[3,4] in South Africa. His use of the term epandrium for the tenth segment is desirable and is adopted here.

I do not propose to change the generic concepts to any great extent but would recognize *Carposcalis* as a group closely related to *Platycheirus* rather than to *Melanostoma.*

These studies indicate the weakness of the genus *Rhysops* and I believe it should have no more than subgeneric status. Basing the separation on antennal differences will not always work out but the genitalia will help to place them. *Melanostoma* s.s., as here defined, would contain very few species. The antennal characters break down when compared to the genital structures. Species like *bolivariensis, neotropicum, altissimum,* and *browni,* all described in the genus *Melanostoma* are thus placed in the genus *Rhysops.* It was this difficulty in generic concepts that caused me to originally misidentify Curran's species *neotropicum* and describe it as *Rhysops columella.*

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1 *Ann. Ento. Soc. America* 14:169–225, 1921.
2 *Trans. Wisconsin Acad. Sci. Arts and Lett.* 40:15, 1950.
3 *Rev. Zool. Bot. Africa* 49:97–139, 1954.
4 *Trans. Roy. Soc. London* 105(17):393–422, 1954.

The genera or subgenera *Melangyna* Verrall, *Hiratana* Matsumura, *Petersina* Enderlein, *Posthonia* Enderlein, and *Pachysphyria* Enderlein are not considered in this paper. Table 1 given below lists the genera studied and in the order in which they were described.

TABLE 1

Date	Genus or Subgenus	Author	Type Species
1825	Platycheirus	Lepeletier and Serville	Syrphus scutatus Meigen
1860	Melanostoma	Schiner	Musca mellinum Linnaeus
1860	Pyrophaena	Schiner	Syrphus rosarum Fabricius
1901	Xanthandrus	Verrall	Musca comptus Harris
1907	Rhysops	Williston	Melanostoma rugosonasus Williston
1937	Carposcalis	Enderlein	Syrphus stegnus Say
1943	Tuberculanostoma	Fluke	Tuberculanostoma antennatum Fluke
1945	Talahua	Fluke	Talahua fervidum Fluke

Discussion of the Generic Groups

Platycheirus Lepeletier and Serville

This is the oldest genus in the tribe, erected in 1925, some 35 years before *Melanostoma*. In the type species there are two characteristics in the genitalia, namely the thumb-like branch to the styles and the sickle-shaped or crescent-shaped superior lobes. The styles, particularly the thumb part, are quite heavily pilose and a few fine hairs are indicated on the superior lobes. The chitinous box in most of the species of *Platycheirus* is bulbous and usually less so in *Carposcalis*. Compare also *Pyrophaena rosarum* with the species of *Platycheirus*.

Carposcalis Enderlein

Enderlein erected this genus for either *punctulatum* or *fenestratum* which he identified as *stegnum* Say. The group is a natural one and I believe is farther removed from *Melanostoma* than from either *Platycheirus* or *Pyrophaena*.

Those species of *Carposcalis* with protruding faces are readily placed. Most of them have spots in the facial pubescence. Those without spots and less protruding faces are more difficult to classify. The genitalia of all those in the appended table under *Carpo-*

scalis are quite uniformly similar. As noted above the genitalia of this group are very similar to those in *Platycheirus* and are kept separate only because of the differences in face and leg characters.

Pyrophaena Schiner

As Hull has indicated this genus is probably only a sub group of *Platycheirus*. The styles of the genitalia are not branched with a thumb-like projection as in *Platycheirus* and in the species *granditarsus* the superior lobes are almost triangular with the inner edge slightly concave, but decidedly sickle-shaped in *P. rosarum* Fabr.

Melanostoma Schiner

A rather small group when all the protruding face forms are removed to *Carposcalis*. The genitalia have uniformly a slender straight style, a broad superior lobe and a non-bulbous chitinous box. In this genus, however, are three species that have genitalia that are intermediate between *Platycheirus* and *Melanostoma*. These are: *M. concinnum* Snow, *M. lata* Curran, and *M. rufipes* Williston. The styles have the beginnings of a "thumb" and the superior lobes are irregular in shape. Perhaps a name should be given to this group but it would be a very difficult one to define without recourse to the genitalia. I therefore consider them only a species group of *Melanostoma*.

Rhysops Williston

The genitalia of this genus as typified in the species *rugosonasus* are somewhat variable but all have non-forked styles that are generally less than two-times as long as wide and with triangular to rectangular superior lobes that are often irregular in shape but never sickle-shaped as in *Platycheirus* or *Carposcalis*. They are definitely related to *Melanostoma* but with much shorter styles. *Pyrophaena granditarsus* Forst., as would be expected, has genitalia quite similar to those of *Rhysops*.

The genitalia of *R. longicornis* Williston are not distinctive enough to separate out *Braziliana* Curran which was erected for this species.

Xanthandrus Verrall

This genus is easily identified by its characters other than the genitalia which are quite similar in structure to those of either

Rhysops or *Melanostoma*. The styles are elongated as in *Melanostoma* but are much broader.

Tuberculanostoma Fluke

This genus from high altitudes in Ecuador has very distinctive genitalia with curved styles; slender, transverse elongated superior lobes and a knobbed ejaculatory hood.

Talahua Fluke

The styles, superior lobes and chitinous box are all very elongate in this genus. These characters are distinctive enough to give this group full generic status.

From these discussions a key to these groups has been prepared based entirely on the genitalia.

KEY TO GENERA OF *Melanostomini* BASED ON GENITALIA OF MALES

1 Styles forked 2
Styles not forked 3
2 Superior lobes crescent-shaped .... *Platycheirus–Carposcalis*
Superior lobes triangular or irregular—never crescent-shaped .... *Melanostoma lata, rufipes, concinnum*
3 Styles three to four times longer than wide 5
Styles no more than two times longer than wide 4
4 Superior lobes crescent-shaped .... *Pyrophaena rosarum*
Superior lobes triangular to irregular in shape .... *Rhysops, & Pyrophaena granditarsus*
5 Superior lobes elongate .... *Talahua fervidum*
Superior lobes very irregular in shape, somewhat triangular to rectangular in shape 6
6 Styles crescent-shaped, ejaculatory hood elongate and knobbed at apex .... *Tuberculanostoma antennatum*
Styles generally straight, ejaculatory hood funnel-shaped .... *Melanostoma, Xanthandrus*

The following list gives the original genus, the date of species publication, the locality of the studied specimens, and references to the illustrations. The only shifting of species from one genus to another has been done in the genus *Melanostoma* either to *Rhysops* or to *Carposcalis*.

Genus *Platycheirus* Lepeletier and Serville, 1825

Type species *scutatus* Meigen

Syrphus albimanus Fabricius 1781—Colorado...... Figures 17 and 18
Scaeva angustatus Zetterstedt 1843—Holland...... Figures 24 and 25
Platycheirus bigelowi Curran 1927—Alaska........ Figures 22 and 23

Syrphus clypeatus Meigen 1822—Switzerland...... Figures 19 and 20
Platycheirus discimanus Loew 1871—Canada...... Figures 29 and 30
Platycheirus erraticus Curran 1927—Canada....... Figures 21 and 26
Platycheirus guttatus Meigen 1948—Germany...... Figures 27 and 28
Scaeva immarginatus Zetterstedt 1849—Colorado... Figures 35 and 36
Platycheirus inversus Ide 1926—Colorado......... Figures 33 and 34
Platycheirus modestus Ide 1926—Alaska.......... Figures 31 and 32
Platycheirus normae Fluke 1939—Wisconsin....... Figures 37 and 38
Platycheirus occidentalis Curran 1927—Colorado... Figures 39 and 40
Syrphus peltatus Meigen 1822—England........... Figures 41 and 42
Scaeva quadratus Say 1823—Wisconsin............ Figures 43 and 48
Syrphus scutatus Meigen 1822—Germany.......... Figures 10 and 11

Genus *Pyrophaena* Schiner, 1860

Type species *rosarum* Fabricius

Musca granditarsus Forester 1781—Colorado...... Figures 126 and 127
Syrphus rosarum Fabricius 1787—So. England..... Figures 9 and 16

Genus *Xanthandrus* Verrall, 1901

Type species *comptus* Harris

Musca comptus Harris 1776—Holland............. Figures 7 and 13
Syrphus bucephalus Wiedemann 1830—Argentina.. Figures 119 and 120
Xanthandrus nitidulus Fluke 1937—Brazil......... Figures 121 and 122

Genus *Carposcalis* Enderlein, 1937

Type species *stegnum* Say

Melanostoma agens Curran 1931—Colorado........ Figures 44 and 45
Melanostoma carinata Curran 1927—Alaska....... Figures 46 and 47
Melanostoma chaetopoda Davidson 1922—Mexico... Figures 49 and 50
Melanostoma chalcanotum Philippi 1865—Chile.... Figures 51 and 52
Melanostoma coerulescens Williston 1886—Colorado Figures 53 and 54
Melanostoma confusum Curran 1924—New York... Figures 57 and 58
Carposcalis ecuadoriensis Fluke 1945—Ecuador.... Figures 59 and 60
Syrphus fenestratum Macquart 1842—Chile....... Figures 56 and 64
Melanostoma inflatifrons Fluke 1945—Ecuador.... Figures 55 and 63
Carposcalis lundbladi Enderlein 1940—Juan Fernandez Islands .... Figures 61 and 62
Melanostoma monticola Jones 1917—Colorado...... Figures 65 and 66
Syrphus obscurus Say 1824—Wisconsin........... Figures 3 and 8
Melanostoma punctulatum Wulp 1888—Argentina.. Figures 67 and 68
Carposcalis saltana Enderlein 1937—Argentina.... Figures 69 and 70
Melanostoma squamulae Curran 1921—Washington Figures 71 and 72
Syrphus stegnum Say 1829—Colorado.............. Figures 73, 74 and 131
Melanostoma trichopus Thomson 1868—California.. Figures 75 and 76

Genus *Rhysops* Williston, 1907

Type species *rugosonasus* Williston

Melanostoma altissimum Fluke 1945—Ecuador..... Figures 95 and 96
Melanostoma bolivariensis Fluke 1945—Ecuador... Figures 97 and 98
Melanostoma browni Fluke 1945—Ecuador........ Figures 107 and 108
Rhysops currani Fluke 1937—Brazil.............. Figures 101 and 102
Rhysops fastigata Fluke 1945—Argentina......... Figures 99, 100 and 132
Melanostoma lanei Fluke 1936—Argentina......... Figures 103 and 104
Melanostoma lineata Fluke 1937—Brazil.......... Figures 105 and 106
Melanostoma longicornis Williston 1888—Brazil.... Figures 4, 14 and 133
Rhysops minuscula Fluke 1945—Argentina........ Figures 109 and 110
Melanostoma neotropicum Curran 1937—Brazil.... Figures 117 and 118
Rhysops nigrans Fluke 1945—Brazil.............. Figures 111 and 112
Rhysops opaca Fluke 1945—Ecuador.............. Figures 115 and 116
Rhysops pollinosa Hull 1942—Argentina.......... Figures 113 and 114
Melanostoma rugosonasus Williston 1891—Mexico.. Figures 6, 15 and 130

Genus *Tuberculanostoma* Fluke, 1943

Type species *antennatum* Fluke

Tuberculanostoma antennatum Fluke 1943—Ecuador Figures 124 and 125

Genus *Talahua* Fluke, 1945

Type species *fervidum* Fluke

Talahua fervidum Fluke 1945—Ecuador........... Figure 123

Genus *Melanostoma* Schiner, 1860

Type species *mellinum* Linnaeus

Group 1

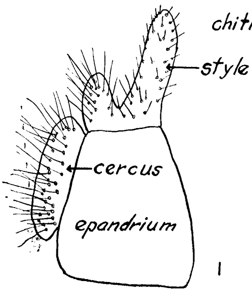
Melanostoma angustatum Williston 1886—Washington .... Figures 77 and 82
Scaeva dubium Zetterstedt 1838—Utah............ Figures 78 and 83
Melanostoma fallax Curran 1923—Alberta......... Figures 79, 84 and 129
Musca mellinum Linnaeus 1758—Libau............ Figures 5, 12 and 128
Melanostoma pictipes Bigot 1884—Tennessee....... Figures 80 and 85
Melanostoma rex Fluke 1945—Ecuador............ Figures 93 and 94
Syrphus scalare Fabricius 1794—Switzerland...... Figures 81 and 86

Group 2

Melanostoma concinnum Snow 1895—Colorado..... Figures 87 and 88
Melanostoma lata Curran 1921—California........ Figures 89 and 90
Chilosia rufipes Williston 1882—Oregon........... Figures 91 and 92

EXPLANATION OF PLATES

All drawings are genitalia made with the aid of the camera lucida, unfortunately not all to the same scale. The smaller forms, especially in *Rhysops* were viewed through a 10x or 15x ocular and a number 7.5 objective; the larger ones usually with a number 3 objective with either 10x or 15x ocular.



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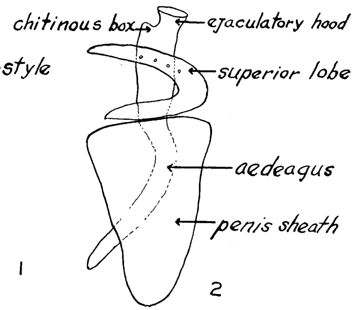

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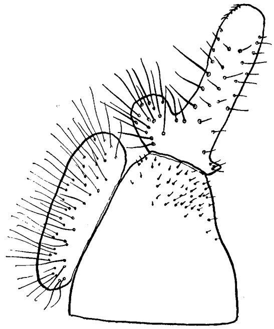
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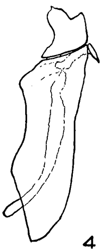
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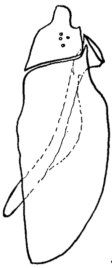
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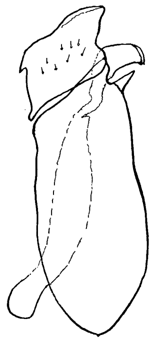
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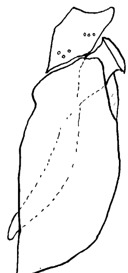
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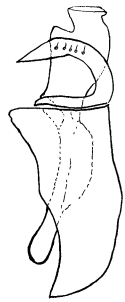
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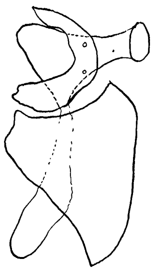
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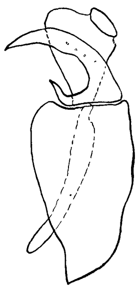
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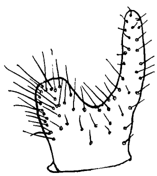
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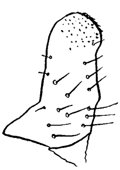
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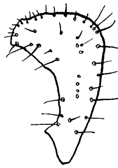
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PLATE I

Figures

1 and 2.—Platycheirus sp. or Carposcalis sp.

3.—Carposcalis obscurum Say.

4.—Rhysops longicornis Williston.

5.—Melanostoma mellinum Linnaeus.

6.—Rhysops rugosonasus Williston.

7.—Xanthandrus comptus Harris.

8.—Carposcalis obscurum Say.

9.—Pyrophaena rosarum Fabricius.

10 and 11.—Platycheirus scutatus Meigen.

12.—Melanostoma mellinum Linnaeus.

13.—Xanthandrus comptus Harris.

14.—Rhysops longicornis Williston.

15.—Rhysops rugosonasus Williston.

16.—Pyrophaena rosarum Fabricius.

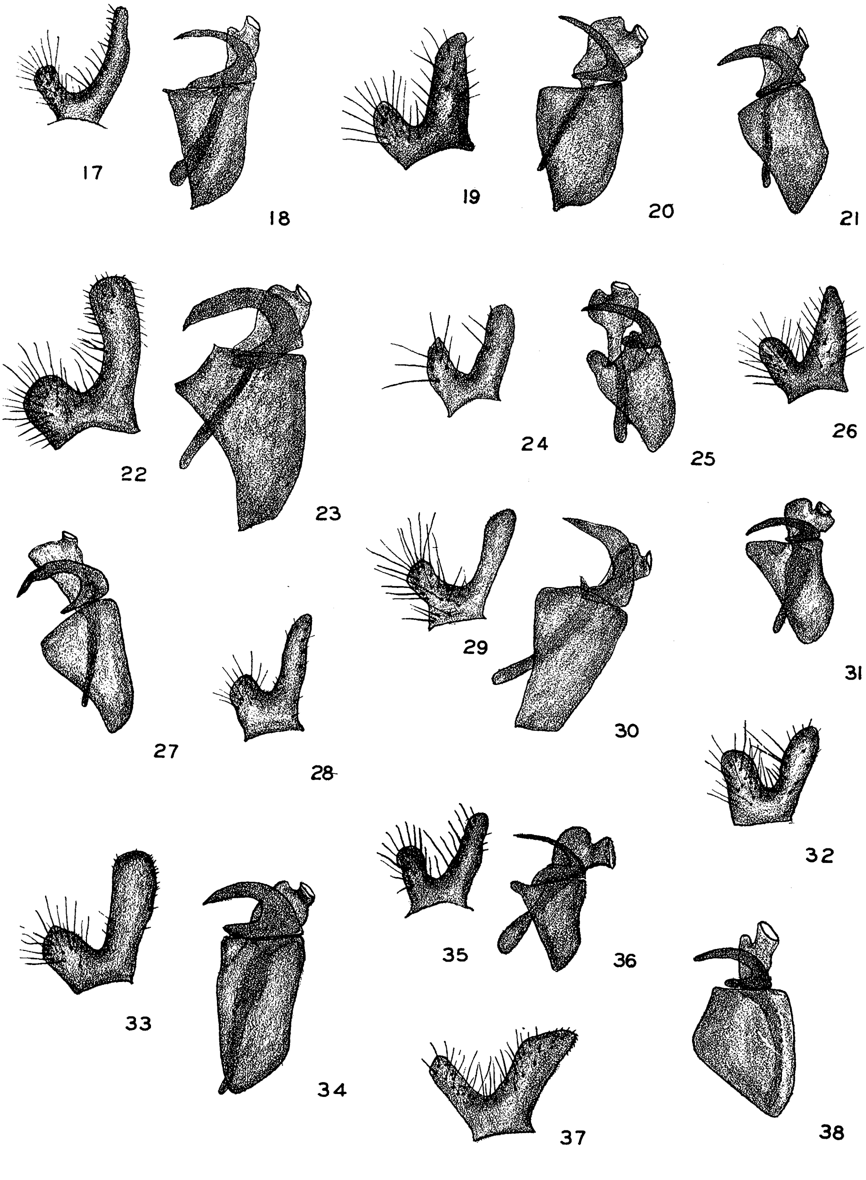
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PLATE II

Figures

17 and 18.—Platycheirus albimanus Fabricius.
19 and 20.—Platycheirus clypeatus Meigen.
21.—Platycheirus erraticus Curran.
22 and 23.—Platycheirus bigelowi Curran.
24 and 25.—Platycheirus angustatus Zetterstedt.
26.—Platycheirus erraticus Curran.
27 and 28.—Platycheirus guttatus Meigen.
29 and 30.—Platycheirus discimanus Loew.
31 and 32.—Platycheirus modestus Ide.
33 and 34.—Platycheirus inversus Ide.
35 and 36.—Platycheirus immarginatus Zetterstedt.
37 and 38.—Platycheirus normae Fluke.

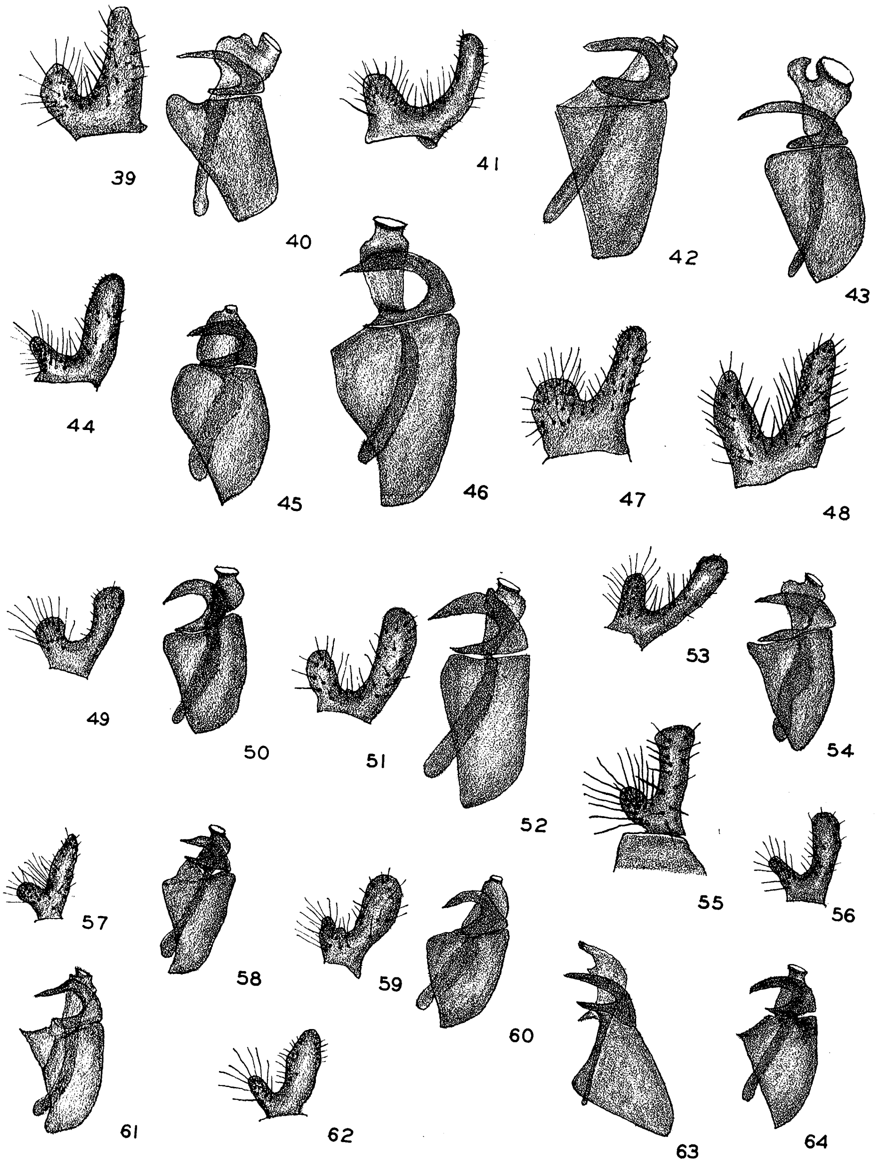
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PLATE III

Figures
39 and 40.—Platycheirus occidentalis Curran.
41 and 42.—Platycheirus peltatus Meigen.
43.—Platycheirus quadratus Say.
44 and 45.—Carposcalis agens Curran.
46 and 47.—Carposcalis carinata Curran.
48.—Platycheirus quadratus Say.
49 and 50.—Carposcalis chaetopoda Davidson.
51 and 52.—Carposcalis chalconotum Philippi.
53 and 54.—Carposcalis coerulescens Williston.
55.—Carposcalis inflatifrons Fluke.
56.—Carposcalis fenestratum Macquart.
57 and 58.—Carposcalis confusum Curran.
59 and 60.—Carposcalis ecuadoriensis Fluke.
61 and 62.—Carposcalis lunbladi Enderlein.
63.—Carposcalis inflatifrons Fluke.
64.—Carposcalis fenestratum Macquart.

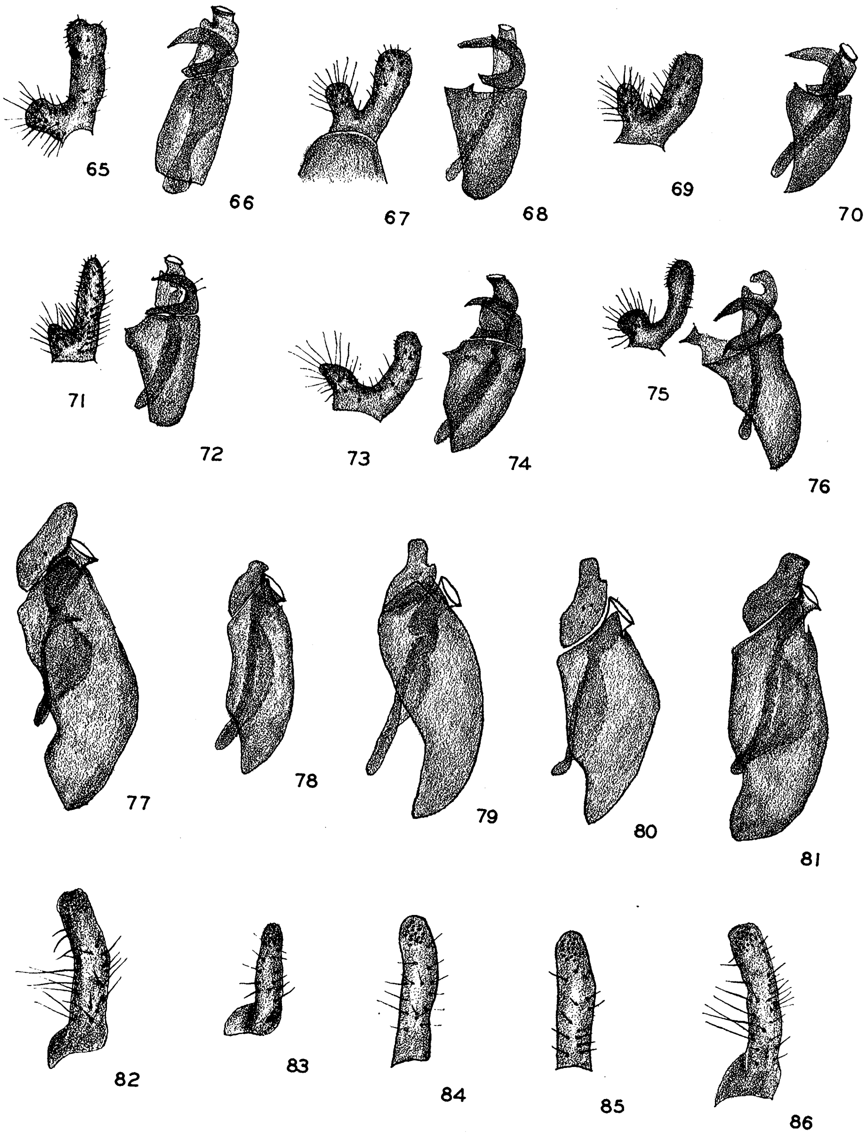
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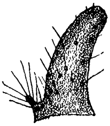
PLATE IV

Figures

65 and 66.—Carposcalis monticola Jones.
67 and 68.—Carposcalis punctulatum Wulp.
69 and 70.—Carposcalis saltana Enderlein.
71 and 72.—Carposcalis squamulae Curran.
73 and 74.—Carposcalis stegnum Say.
75 and 76—Carposcalis trichopus Thomson.
77.—Melanostoma angustatum Williston.
78.—Melanostoma dubium Zetterstedt.
79.—Melanostoma fallax Curran.
80.—Melanostoma pictipes Bigot.
81.—Melanostoma scalare Fabricius.
82.—Melanostoma angustatum Williston.
83.—Melanostoma dubium Zetterstedt.
84.—Melanostoma fallax Curran.
85.—Melanostoma pictipes Bigot.
86.—Melanostoma scalare Fabricius.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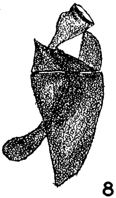
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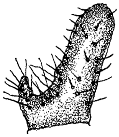
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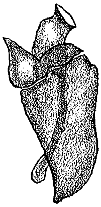
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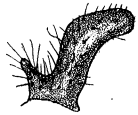
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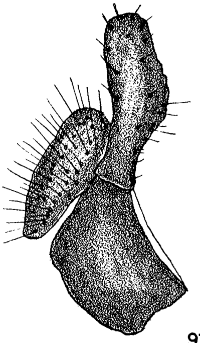
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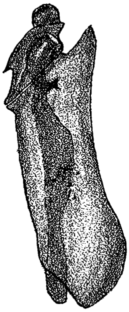
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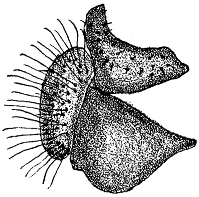
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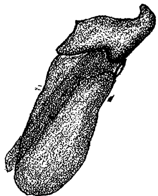
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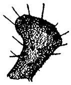
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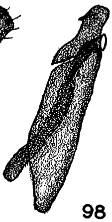
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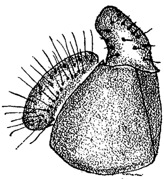
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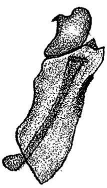
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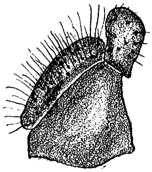
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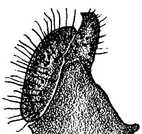
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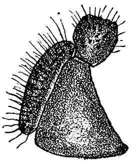
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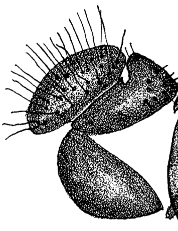
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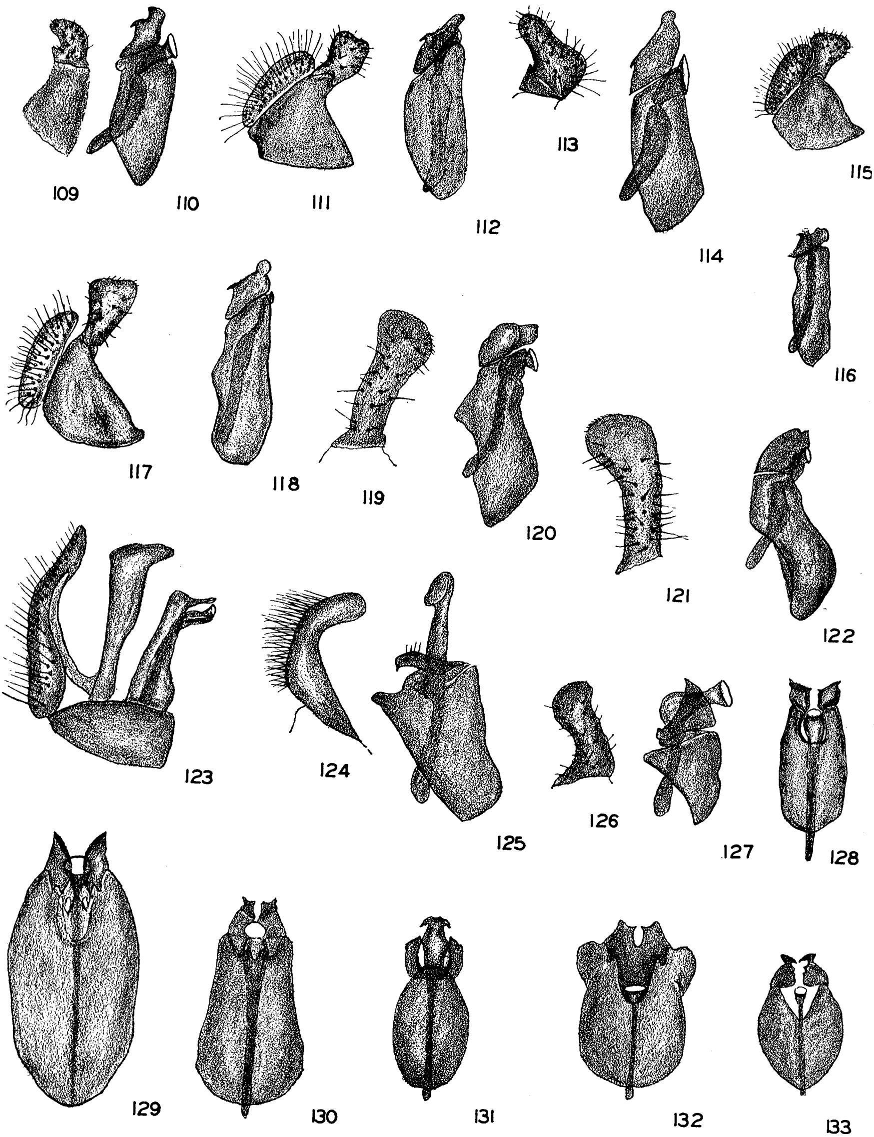
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THE CONTROL OF THE GROWTH OF ALGAE WITH CMU[1]

GEORGE P. FITZGERALD
Hydraulic and Sanitary Laboratory, University of Wisconsin

INTRODUCTION

The need for control measures to eliminate excessive growths of algae and nuisance conditions in fresh waters is becoming more and more critical as the fertility of lakes and streams increases. A number of chemicals have been used (4, 6, 16), ranging from copper sulfate, first used in this country in 1904 (14), to various organic chemicals, which are now being investigated. Inorganic chemicals, other than copper, include chlorine (2, 13), potassium permanganate (18), colloidal silver (3, 7), activated carbon (10, 15), and ammonium sulfate (17). A serious disadvantage in their use is their lack of specificity, especially as some of them may accumulate over the years to produce toxic conditions to both plants and animals.

This disadvantage may be avoided by the adoption of comparatively short-lived organic chemicals, examples of which are dehydroabietylamine acetate (Rosin Amine D Acetate or RADA) and 2, 3-dichloronaphthoquinone (dichlone or phygon). There are recent reports that RADA is very effective in controlling filamentous green algae (5, 11) without affecting the growth of unicellular algae (12). Dichlone, when used in very low concentrations (less than 0.1 ppm) is effective against bloom producing blue-green algae and apparently without harm to other types of algae, plants, or animals in the lakes. (7, 8).

Results of experiments are presented which demonstrate that CMU[1] is effective in controlling the growth of a large number of algae. CMU has been used extensively as an herbicide (19) and has also been previously reported to be toxic to algae (16). This report deals primarily with tests of its use for controlling the growth of algae in the presence of other organisms, as in aquaria.

MATERIALS AND METHODS

A total of 22 species of algae (12 blue-green, 8 green, and 2 diatom species), as well as higher aquatic plants and fish have been used to test the toxicity and selective action of CMU. The algae were young, rapidly growing, unialgal cultures from laboratory stock cultures and were tested in either dilute, alkaline modified

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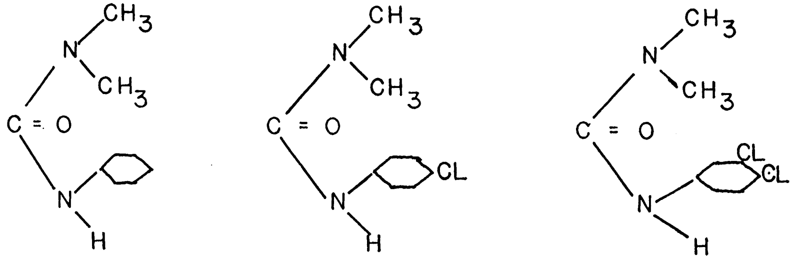
[1] 3-(p-chlorophenyl)-1, 1-dimethylurea.

Chu No. 10 (9) or a more concentrated, neutral Allen's (1) medium. An exception to this was with the three species, *Cladophora, Rhizoclonium,* and *Spirogyra* which were freshly collected from lakes or green-house culture tanks for each experiment. These large forms were tested in Lake Mendota water enriched with sufficient sodium nitrate, potassium phosphate, and ferric citrate salts to give an additional 20 ppm of nitrogen, 2.0 ppm of phosphorus, and 0.5 ppm of iron. Lake water enriched in this manner was also used in tests with various higher aquatic plants.

The CMU was added to the algal cultures in the early logarithmic growth phase. Cell counts and dry weights, as well as visual estimates, were employed to determine differences in growth between control and treated cultures exposed to the chemical for periods up to four weeks. A Spencer Bright Line Haemocytometer was used for cell counts. For dry weight determinations, the algae were centrifuged, washed in distilled water, recentrifuged, and dried to constant weight (24 hours) in tared weighing bottles at 63° C. Visual estimates of the effect of treatments were, of course, approximations obtained by matching the growth in treated cultures and controls and were recorded as the relative percentage inhibition, i.e., 0, 25, 50, 75, 90, and 100 per cent inhibition of growth.

Serial concentrations of CMU were used in each experiment. For brevity only the lowest concentration giving complete inhibition of growth will be reported for each species. A typical example is the following experiment with *Gloeocapsa dimidiata.* The concentrations tested were 0, 0.05, 0.2, 0.8, and 1.6 ppm and the corresponding relative growth values, based on dry weight measurements after 21 days treatment, were 100, 81, 16, 13, and 2 per cent respectively. The latter two cultures appeared to be dead. All experiments reported have been repeated, in some instances up to 19 times in the course of the investigation.



3-PHENYL-1, 1-DIMETHYLUREA (F W)

3-(P-CHLOROPHENYL)-1, 1-DIMETHYLUREA (C M U)

3-(3, 4-DICHLOROPHENYL)-1, 1-DIMETHYLUREA (D W)

FIGURE 1.

Some comparative tests have been carried out with other chemicals: 3-phenyl-1, 1-dimethylurea (FW); 3-(3, 4-dichlorophenyl)-1, 1-dimethylurea (DW); cupric chloride; cupric sulfate; 3-amino-1, 2,4-triazole; pentachlorophenol; Aquasan (colloidal silver); RADA; 2-methylnaphthoquinone; and dichlone. The first two chemicals FW and DW, are closely related to CMU, as illustrated in Fig. 1. Both FW and DW were obtained as the 80% commercial products, from the E. I. du Pont de Nemours Co. Tests with the commercial 80% pure preparation of CMU showed that on a molar basis it was equally as effective as pure CMU.

Results

Toxicity of CMU to Various Species of Algae. The toxicity of CMU to algae is indicated by the results summarized in Table 1. The concentration required for complete inhibition of growth and

TABLE 1

CMU CONCENTRATION REQUIRED FOR COMPLETE INHIBITION OF GROWTH OF VARIOUS SPECIES OF ALGAE

Species	CMU Conc. for Complete Inhibition of Growth (ppm)	Method of Determining Effect	No. of Tests	Tested in Two Media[1]
Blue-green algae				
Coccochloris Peniocystis	0.8	Visual	4	x
Gloeocapsa dimidiata	0.8	Dry weight	2	....
Microcystis aeruginosa	0.5	Cell count	6	....
Arthrospira Jenneri	0.8	Dry weight	4	x
Phormidium tenue	0.8	Dry weight	2	....
Phormidium autumnale	1.0	Visual	2	x
Lyngbya Birgei	0.5	Visual	2	....
Nostoc muscorum	0.5	Dry weight	4	x
Anabaena spiroides	0.8	Dry weight	2	....
Calothrix parietina	0.5	Dry weight	4	x
Amphithrix janthina	0.2	Dry weight	2	....
Gloeotrichia echinulata	0.8	Dry weight	4	....
Green algae				
Chlamydomonas sp.	1.6	Dry weight	4	x
Chlorella pyrenoidosa	1.5	Dry weight	4	x
Scenedesmus sp.	1.0	Cell count	4	x
Stichococcus sp.	0.8	Dry weight	4	x
Stigeoclonium sp.	0.8	Dry weight	2	....
Cladophora sp.	2.0	Visual	3	....
Rhizoclonium sp.	2.0	Visual	4	....
Spirogyra sp.	2.0	Visual	3	....
Diatoms				
Diatom sp. (A)	0.5	Dry weight	2	x
Diatom sp. (B)	0.5	Visual	2	....

[1]Modified Chu No. 10 and Allen's.

the method used to measure the effect of the chemical are listed for each species. The last two columns give the number of separate experiments carried out with each test organism and indicate which species were tested in both modified Chu No. 10 and Allen's media. Similar results were obtained with any given concentration of CMU in either medium. It has been observed for the majority of the species tested that, where the algae were inhibited by 75% or more, they never recovered sufficiently to produce the high levels of growth of the control cultures and, in most cases, they seemed to be gradually dying off.

The growth of the 12 species of blue-green algae was inhibited 75% or more by CMU concentrations close to 1.0 ppm. This includes both planktonic bloom producing forms, such as *Microcystis,* and nonplanktonic algae, such as *Nostoc.*

Of the five unialgal cultures of green algae tested, two required somewhat higher concentrations (*Chlorella,* 1.5 ppm and *Chlamydomonas,* 1.6 ppm) for complete inhibition of growth. This may be related to the fact that they were the most rapidly growing species under the conditions of the tests so that more cells were present when the chemical was added. In one test the number of cells per ml. of a *Chlorella* culture increased from 650,000 to 5,200,000 in two days, whereas in a *Microcystis* culture the cell count only increased from 550,000 to 1,400,000 cells per ml. during the same period.

The three species of filamentous green algae, *Cladophora* sp., *Rhizoclonium* sp., and *Spirogyra* sp., were killed by 2.0 ppm of CMU. In this case, the control cultures were kept alive in enriched lake water, but they were not actually growing at noticeable rates. In a few experiments with growing *Rhizoclonium,* 0.5 ppm of CMU killed the plants.

The diatoms, which had been isolated by plating from growths on trickling filters at a sewage treatment plant (sp. A) and from a drinking fountain scum (sp. B), were killed by 0.5 ppm of CMU. In general, diatoms would appear to be more susceptible than the other algae, because they seldom were observed in treatments with low concentrations of CMU where various kinds of algae did grow, even though diatoms grew abundantly in the control vessels.

Toxicity of CMU to Mixed Populations of Unicellular Algae. The effectiveness of CMU has been compared with that of other algicides in preventing the growth of "wild populations" of algae. Stock cultures were prepared of blue-green and green algae and diatoms in enriched lake water into which various organisms collected from Lake Mendota, from growths on drinking fountains, etc. had been added to give thriving mixed populations. The species present included various *Oscillatoria, Scenedesmus* (several species), *Chlorella, Chlamydomonas, Kirchneriella,* and *Selenastrum,* as well as many forms of diatoms.

The tests were made on subcultures in the same media as used above (modified Chu No. 10 and Allen's solutions). The chemicals were added in serial dilutions and were introduced either at the time of inoculation with the stock cultures, or 2–3 days later after growth had started. Effects of treatments were recorded only in terms of visual observations.

Results of two experiments are shown in Table 2. It may be seen that CMU is more effective than any of the other chemicals, including those now in general use as algicides. Where growth was started three days in advance of the treatment, even 12.5 ppm of CMU gave only 90 per cent inhibition within a 10 day period.

TABLE 2

COMPARISON OF THE TOXIC EFFECT OF VARIOUS CHEMICALS ON MIXED ALGAE CULTURES

Chemical	Conc. (p.p.m.)	Effect on Algae
Expt. No. 11 [1]		
3-Amino-1, 2, 4-triazole	12.5	No effect
Dichlone	0.5	No effect
Dichlone	2.5	Sl. inhibition
Cupric chloride	2.5	Sl. inhibition
Aquasan (colloidal Ag)	2.0	Sl. inhibition
Aquasan (colloidal Ag)	20.0	50% inhibition
Rosin Amine D Acetate	2.5	No effect
Rosin Amine D Acetate	12.5	Sl. inhibition
2-Methylnaphthoquinone	2.5	No effect
2-Methylnaphthoquinone	12.5	Sl. inhibition
CMU	2.5	75% inhibition
CMU	12.5	90% inhibition
Expt. No. 12 [2]		
3-Amino-1, 2, 4-triazole	40.0	No effect
Dichlone	1.0	No effect
Dichlone	10.0	75% inhibition
Cupric sulfate	2.5	No effect
Rosin Amine D Acetate	2.0	No effect
Rosin Amine D Acetate	10.0	Sl. inhibition
CMU	1.0	100% inhibition

[1] Chemicals were added 3 days after inoculation; observations of effects made 10 days after treatment
[2] Chemicals added at time of inoculation; observations of effects made 4 days later.

In the second experiment (No. 12), with the chemicals supplied at the time of inoculation, fair to good growth was established within four days time in all cultures except those with CMU (1.0 ppm) and dichlone 10 ppm. The treatment with 1.0 ppm dichlone had no effect.

Comparisons of the Toxicity of CMU and Related Compounds. Comparisons of the toxic effects of CMU with that of two related chemicals, one without a halogen substituent, 3-phenyl-1, 1-dimethylurea (FW) and the other with two chlorine atoms, 3-(3, 4-dichlorophenyl)-1, 1-dimethylurea (DW), are summarized in Table 3.

TABLE 3

COMPARISON OF THE TOXICITY OF DIFFERENT CONCENTRATIONS OF CMU AND RELATED COMPOUNDS TO VARIOUS SPECIES OF ALGAE

Species	Conc. p.p.m.	Effect of Compound as Per Cent Growth Inhibition		
		CMU [1]	FW [2]	DW [3]
Microcystis aeruginosa [4]	1.0	50	0	90
	2.0	....	....	100
	5.0	75	....	100
	10.0	100	50	100
Rhizoclonium sp.	1.0	0	0	100
	2.0	100	0	100
	5.0	100	0	100
	10.0	100	100	100
Cladophora sp.	2.0	100	0	100
	5.0	100	0	100
	10.0	100	100	100
Spirogyra sp.	2.0	100	0	100
	5.0	100	0	100
	10.0	100	100	100

[1] 3-(p-chlorophenyl)-1,1-dimethylurea.
[2] 3-phenyl-1,1-dimethylurea.
[3] 3-(3,4-dichlorophenyl)-1,1-dimethylurea.
[4] Cultures 4 days old when chemicals added.

In the tests with *Microcystis*, the chemicals were added after the algae had grown for four days (to ca. 4,000,000 cells per ml.) and as a result more chemical was required to stop the growth than with the other tests where the chemicals were added at the time the test cultures were started. The data indicate that the toxicity increases with the halogen content of the molecules, DW being more and FW less effective than CMU itself.

Toxicity of CMU and Other Compounds to Higher Aquatic Plants. The toxicity of several compounds to cultures of duckweed

(Lemna minor) has been investigated. In the first two experiments plants were taken directly from Lake Mendota and placed in enriched lake water. The chemicals were added immediately after planting. The results of treatments with CMU, DW, dichlone, and pentachlorophenol from Experiment 10-C, were recorded after 25 days and are presented in Table 4. In a later experiment (10-D) plants were used which had been cultured in the laboratory.

TABLE 4

COMPARISON OF THE TOXICITY OF SEVERAL COMPOUNDS TO DUCKWEED *(Lemna minor)* CULTURES

COMPOUND	CONC. P.P.M.	EFFECT OF TREATMENT ON		
		Duckweed roots	General condition of Duckweed	Growth of unicellular algae
Experiment No. 10-C[1]				
Control	0	Green, many	All healthy	Heavy
CMU	1.0	None	All healthy	None
	2.5	None	All healthy	None
	5.0	None	50% killed	None
DW	1.0	None	90% killed	None
	2.5	None	100% killed	None
Dichlone	1.0	Green, many	All healthy	Heavy
Pentachlorophenol	5.0	Green, many	All healthy	Heavy
Experiment No. 10-D[2]				
Control	0	Green, many	All healthy	Heavy
CMU	0.25	Very few	All healthy	Light
	0.50	Very few	All healthy	Light
	1.00	None	All healthy	None
	2.50	None	All healthy	None
	5.00	None	50% killed	None
DW	0.25	None	All healthy	Light
	0.50	None	All healthy	Light
	1.00	None	All healthy	None
	2.50	None	90% killed	None
	5.00	None	100% killed	None

[1]Observations after 25 days.
[2]Observations after 21 days.

The roots of duckweed are sensitive indicators of their growth conditions and are often shed in unfavorable media. The plants from the lake had apparently shed their roots as none were observed at the time they were collected. The laboratory cultures, on the other hand, had many well developed green roots. It may be seen from the table that in the first experiment, roots developed in the controls and in the cultures treated with dichlone or pentachlorophenol, but none developed in the cultures treated with CMU and DW. This was true for all three concentrations tested. The 1.0 and 2.5 p.p.m. concentrations of CMU appeared to be without effect on the "fronds", but the 5.0 p.p.m. concentration killed 50 per cent of the plants.

In a later experiment where the plants had well developed roots at the start, all concentrations of DW down to 0.25 p.p.m. and concentrations of CMU of 1.0 p.p.m. or more caused the roots to be shed and none grew out; even the 0.25 and 0.5 p.p.m. concentrations of CMU markedly reduced the root development. As compared with this, only the 5.0 p.p.m. CMU and 2.5 and 5.0 p.p.m. DW concentrations tended to kill the plants. Dichlone (1.0 p.p.m.) or pentachlorophenol (5.0 p.p.m.) had no visible effects even on the roots of the duckweed plants.

In time, contaminating unicellular algae developed to form heavy growths in the control cultures and also in the treatments with dichlone or pentachlorophenol. In the cultures treated with CMU or DW, on the other hand, growth of algae was suppressed by 1.0 p.p.m. concentrations. With the lower concentrations, the inhibition of algal growth occurred roughly in proportion to the inhibition of root growth on the higher plants by the treatments.

The toxicity of CMU to *Elodea canadensis* was determined by placing 6 inch, terminal sprigs in enriched lake water. CMU was added at the same time as the plants and visual observations were recorded at intervals during periods up to 28 days. A total of nine experiments have been concluded and the summary of data presented in Table 5 shows the effects of various concentrations of CMU on the *Elodea.* The effects of the chemical on small snails kept in the cultures and on the development of contaminating unicellular algae in some of the cultures were also recorded.

TABLE 5

EFFECT OF CMU ON *Elodea canadensis* CULTURES

CONC. (P.P.M.)	EFFECT OF TREATMENT ON		
	Elodea	Snails	Growth of unicellular algae
0.0	No effect	No effect	Heavy
1.0	No effect	No effect	None
5.0	No effect	No effect	None
10.0	Only terminal growth	No effect	None
20.0	Killed	No effect	None
60.0	Killed	Killed	None

The *Elodea* sprigs exhibited no adverse effects from CMU concentrations up to 5.0 p.p.m. At CMU concentrations around 10 p.p.m. there was a very gradual decay of the older portions of the sprigs, but concentrations of 20 p.p.m. or more were required to kill the plants within a four-week period. No effect on the snails was observed with CMU concentrations less than 60 p.p.m. The growth of contaminating unicellular algae was prevented in all cases by CMU concentrations of 1.0 p.p.m. or more.

Some other aquatics, *Vallisneria americana,* (tape grass), *Salvinia rotundifolia,* (water velvet), *Ceratophyllum demersum,* and a species of *Myriophyllum* have also been tested to some extent and seem to behave in much the same manner as *Elodea.*

TABLE 6

EFFECT OF CMU AND RELATED COMPOUNDS ON MIXED CULTURES OF ALGAE AND *Elodea*

Compound	Conc. (p.p.m.)	Effect of Treatment on		
		Elodea	Filamentous green algae	Unicellular algae
Control	0	No effect	No effect	Heavy
CMU	1.0	No effect	Killed	None
	2.5	No effect	Killed	None
	5.0	No effect	Killed	None
	10.0	Killed	Killed	None
FW	2.0	No effect	No effect	Light
	10.0	No effect	Killed	None
	20.0	Killed	Killed	None
DW	1.0	No effect	Killed	None
	2.5	No effect	Killed	None
	5.0	Killed	Killed	None

Effect of CMU on Mixed Algae and Higher Plant Populations. Since the toxicity of CMU to the various species of algae and to the higher aquatic plants, such as *Elodea* was quantitatively apparent, it was decided to test the effectiveness of CMU in preventing algal growth in mixed cultures of blue-green and green algae, diatoms, and *Elodea* plants. Culture solutions of 0.1 to 10 liter volume of enriched lake water were planted with terminal sprigs of *Elodea* plus small mats of the green filamentous algae, *Rhizoclonium* sp., and *Spirogyra* sp., and a mixture of unicellular blue-green algae, green algae, and diatoms. Various dilutions of CMU or of its related compounds, FW and DW, were added at the time of inoculation and the effect of the treatments recorded at various times up to nine weeks. A total of 28 experiments with mixed cultures of this type have been conducted. A summary of the main results is given in Table 6.

It can be seen from these data that concentrations of CMU from 1.0 to 5.0 p.p.m. effectively killed the filamentous green algae and prevented the growth of any unicellular algae and diatoms without having any apparent adverse effects on the *Elodea.* Concentrations of 2.0 p.p.m. of FW had no effect on the green filaments and very little effect on the other algae or diatoms. The highest concentration of DW (5.0 p.p.m.) killed the *Elodea*, but the lower concentrations only killed or prevented the growth of the algae. *Ceratophyllum demersum,* tape grass, and a species of *Myriophyllum,* were used instead of *Elodea,* and showed about the same resistance to CMU. In general, it was found that CMU concentrations as low as 0.5 to 1.0 p.p.m. are sufficient to prevent any unicellular algal species from growing up in mixed cultures with the higher aquatics. Only considerably higher concentrations, at least 2.5 to 5.0 p.p.m., affected the growth of *Elodea* or other aquatic species tested. In the presence of still higher concentrations, which stop the growth of *Elodea,* resistant forms of blue-green species were sometimes found to develop on the walls of the containers or on the aquatic plants after long exposure periods.

Toxicity of CMU to Fish. In the practical use of algicides, their toxicity to animals must also be considered. Therefore, tests on the effect of CMU on seven species of fish have been included in this study. In one experiment, a number of small (2–3 inch) bluegills *(Lepomis macrochirus macrochirus)*, green sunfish *(L. cyanellus)*, crappie *(Pomoxis nigromaculatus)*, and bluntnose minnows *(Hyborhynchus notatus)* were tested in 10 to 20 liter aerated aquaria (temperature, 23–24° C.) with CMU concentrations of 10, 20, and 40 p.p.m. No adverse effects on the fish were apparent in any of the aquaria after 23 days, when the experiments were terminated. An experiment, with guppies (*Lebistes* sp.) carried out in 1½ liter, unaerated aquaria with CMU concentrations of 10, 25, and 50 p.p.m. showed no harmful effects on the fish over a period of 35 days.

In an experiment in which bluegills and sunfish were placed in CMU concentrations of 120 p.p.m., it was found that after 3 to 7 days, the fish gradually became affected by the chemical. The first indication was that the fish turned their heads downward and stayed in that position for extended periods, unless they were disturbed. If the fish affected in this manner were transferred to untreated aquaria, they would recover and appear to be perfectly normal within one to two hours. Therefore, the toxic effects were not permanent at this stage and fish subjected to the high concentrations of CMU could be saved by removing them. When these fish were transferred back to the high CMU concentrations, they again turned head downward. The fish that were not removed at this "head downward" stage eventually turned on their sides and died. In five experiments in which the CMU was added in the form of slowly dissolved pellets (0.5 g. pellet in 10 liters of solution), crystalline material was still present after 73 or more days, growth of algae was prevented, and there was no injury to the growth of higher aquatics or toxicity to fish.

Seven tests with 2.5 liter, unaerated aquaria (common household type) containing goldfish (*Carassius* sp.), guppies (*Lebistes* sp.), zebra fish (*Pterois volitans*), bluntnose minnows, or bluegills have shown that aquaria treated with concentrations of CMU as low as 0.5 p.p.m. remained clean for eight weeks, while untreated controls became fouled with dense, repugnant growths of green algae in suspension and coating the sides of the aquaria in only one week. Two baby guppies (one day old) have been raised in an aquarium with a concentration of 15 p.p.m. for 16 weeks with no apparent harmful effects.

In all these experiments with fish, CMU concentrations much higher than those which would be recommended for use in aquaria have been tested in order to detect any adverse effects that might be produced. Only in those experiments where the chemical was dissolved first and then added to the aquaria as a solution to make concentrations of more than 100 p.p.m. were any adverse effects noted on fish.

Discussion

The quantitative toxicity tests with unialgal cultures indicated that CMU is particularly effective in killing or preventing the growth of a large number of algae, including blue-green, green, and diatom species. However, considerably more chemical is required to kill an already established algal culture than to prevent the growth of algae. Therefore, by utilizing this fact the growth of algae can be prevented by the use of low CMU concentrations, 0.5 to 1.0 p.p.m., in situations where higher concentrations might be detrimental to other aquatic plants, as demonstrated in the various experiments with mixed populations in aquaria.

Few chemicals are known to be effective in algae-control for long periods of time. Phygon, RADA, copper, and chlorine are adapted to killing existing populations, but, under normal circumstances, repeated applications must be made to control successive growths of algae. In contrast, low concentrations of CMU will prevent the growth of algae for quite extended periods. Another factor which increases the usefulness of CMU as a practical algicide is its high toxicity to a wide range of algal species and relatively low toxicity to the various species of fish tested. Both Phygon and RADA are much more selective in their algicidal activity. Copper and chlorine are effective against a large number of algae, but care must be used in their application because of their corrosive action and their high toxicity to animals. Chemicals closely related to CMU, particularly 3-(3,4-dichlorphenyl)-1, 1-dimethylurea (DW), may have comparable, and in some respects perhaps superior properties as algicides. However, DW may be more toxic to fish or less selective in its action on plants than is CMU.

Although it has been shown that the concentrations of CMU that prevented the growth of algae had no apparent harmful effects on the various aquatic plants tested, it should be pointed out that in these tests the growth of the aquatic plants was not a measured factor. The experiments with duckweed *(Lemna minor)* demonstrated that, although the fronds looked healthy, there was not as much new growth in treated vessels as in the controls. CMU, when present in sublethal concentrations, may arrest or slow down the growth of the aquatic plants much the same as it prevents the further growth of algae. Only with tests on rapidly growing cultures of aquatic plants can this be actually tested.

It has been pointed out in some of the studies that resistant strains of algae occasionally grew in cultures treated with CMU concentrations high enough to visibly harm the aquatic plants present. In general, it was found that if the concentration of CMU added to mixed algal and higher plant cultures was kept near 0.5 to 1.0 p.p.m., the higher plants appeared to remain healthy and there was no appearance of resistant algae.

It should be emphasized that the action of low concentrations of CMU on algae is as a preventive of growth rather than merely killing the existing population. In attempting to make practical applications of this chemical, therefore, it should be used before algal populations become large enough to be obnoxious. It does not appear to be as effective for killing existing populations as some of the other algicides available. Therefore, CMU possibly could be used to prevent further grow of algae after other chemicals had been used to kill existing algal growths. However, further testing is required to determine the most efficient means of utilizing this type of compound for controlling the growth of algae in specific instances.

SUMMARY

The compound 3-(p-chlorophenyl)-1,1-dimethylurea (CMU) has shown promise as an algicide. Quantitative tests with 22 species of algae, including blue-green, green, and diatom species, as well as

tests with wild, mixed populations have indicated that CMU concentrations of 0.5 to 1.0 p.p.m. prevented algal growth. Concentrations two to five times higher were required to cause observable changes in the higher plants tested. In experiments with fish, CMU concentrations as high as 40 p.p.m. apparently were not harmful.

There is evidence that CMU is more effective in preventing the growth of algae than in killing existing populations. Therefore, its use is suggested in preventing the further growth of algae where the previous algal population has been reduced by other measures.

Acknowledgements

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The author wishes to thank Folke Skoog and G. C. Gerloff of the Botany Department, University of Wisconsin, for their suggestions and aid in the preparation of this paper. All work reported was carried out by the author while a member of the staff of the Botany Department, University of Wisconsin.

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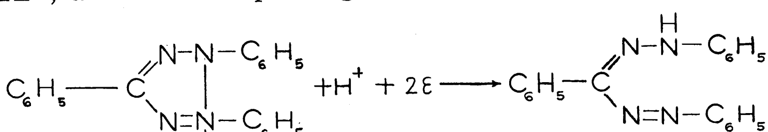
THE DECOMPOSITION KINETICS OF 2,3,5-TRIPHENYL-(2*H*)-TETRAZOLIUM HYDROXIDE

SAMUEL WEINER
University of Wisconsin Extension Center, Wausau, Wis.

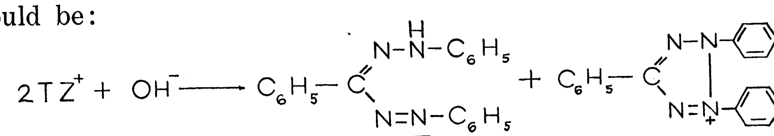
The properties of the tetrazolium salts and their formazans (1, 2) have been of interest to botanists, cytologists, bacteriologists, and chemists for several years. The chemistry of the tetrazolium salts and formazans has been well studied since before 1892 (3) and has recently been reviewed by Nineham (4) and Reid (5). The 2,3,5-triphenyl-(2*H*)-tetrazolium ion (I), hereinafter symbolized as TZ^+, and its corresponding formazan (II) have been particu-



I   II

larly well studied. The many uses of TZ^+ in biology, chemistry and physiology are based on the reduction of the colorless TZ^+ by enzymes or by alkaline reducing agents to the insoluble deep-red formazan (4, 5, 6, 7), whose yield is determined colorimetrically. However, in alkaline solution another reaction is possible, the decomposition of the TZ^+OH^- to several products and particularly to a red gum containing or resembling the formazan. Such red resins or colors have been observed on keeping TZ^+OH^- at 100° C. (3, 7), or on evaporating TZ^+OH^- *in vacuo* at 0° C., or on dissolving TZ^+Cl^- in such basic solvents as morpholine or ethanolamine at room temperatures. Cheronis and Stein (7) ascribe the red color to a rearrangement of TZ^+OH^- to $C_6H_5N{=}N{-}C(C_6H_5){=}N{-}NOH(C_6H_5)$, accompanied by decomposition of this compound to others; the postulated compound, the hydroxy-formazan, is described by these authors as insoluble, colored, and in equilibrium with the isomeric ion-pair, TZ^+OH^-. The stoichiometric equation for the decomposition by this route would be $TZ^+ + OH^- \rightarrow \ldots\ldots$

On the other hand, if the formazan is produced by a dismutation of TZ^+ similar to that which Weygand and Frank (8) found to occur in irradiated alkaline solution, the stoichiometric equation would be:



II

Jambor (9) states that a reaction analogous to the above occurs in strongly alkaline solution in the dark. Decomposition or dismutation can also occur in neutral solution exposed to ultrasonic vibration (10).

In spite of the many products of the reaction and their vague characterization, it was deemed useful to measure the kinetics of both the aqueous alkaline decomposition of TZ^+ and the formation of triphenyl formazan, as shown by its characteristic color. The speed of the breakdown of TZ^+ by OH^- would set practical limits to the analytical methods (6, 7, 11, 12) based on the color of the formazan produced from TZ^+ by alkaline reducing agents; hence the production of triphenyl formazan in the work here reported was measured colorimetrically at the spectral absorption peak of the formazan. This was justified by the color being the observable variable in the analytical applications of TZ^+, by the reported isolation of triphenyl formazan in alkaline TZ^+Cl^- solution reddened by radiation (8), and by the coincidence of the spectral absorption curves in the region of the main absorption band of both triphenyl formazan and the solid resin product of this decomposition.

This present work was on the reaction between TZ^+OH^- and sodium hydroxide in water at 65.7° C. Stoichiometrically, the reaction was $TZ^+ + OH^- \rightarrow$ . . . . . .; kinetically, it was first order in TZ^+ but second order in OH^-. The empirical velocity constants, k, and the standard deviations, σ, for each run are tabulated below:

VELOCITY CONSTANTS OF DECOMPOSITION OF TZ^+ AT 65.7° C.

Initial $[TZ^+]$	Initial $[OH^-]$	$10^5\ k$ liter^2 mole^{-2}	$10^6\ \sigma$ sec.$^{-1}$
0.0151 *M.*	0.1902 *M.*	7.15	0.05
0.0149	0.3167	7.18	0.08
0.0154	0.2893	7.37	0.12
0.0157	0.2986	7.40	0.05
0.0155	0.3403	7.63	0.17
0.0115	0.5335	7.90	0.08

The triphenyl formazan could be seen forming as a red haze in the solution, eventually coagulating. The formazan yield followed a logistic or autocatalytic law, but was only a twentieth of the consumption of the TZ^+. Formazan is hardly the main product. The formazan yield depended on the initial concentrations of the reagents; when plotted as a function of $k^2[TZ^+]_0[OH^-]_0^6t^2$, the formazan yields in these experiments fell on lines that were straight to twice the inflection point time and diminished in slope beyond that. The formazan yield at the inflection points in the plot of formazan yield against time was relatively uniform, about 2.6×10^{-5} *M.*, although the inflection point time varied over a fiftyfold range. In all cases the solution became yellow and the final solid products included much tarry matter.

Experimental. The TZ^+OH^- stock solutions, .012 to .016 *M.* and at *p*Hs of 10.8 ± .2, were treated with enough saturated NaOH solution to bring the *p*H to 12.0 while the stock solution was agitated at 65.7° C. At this temperature it was necessary that the NaOH concentration be 0.2 to 0.5 *M.* to secure a convenient rate of reaction; the NaOH served not only as a reactant but also as an "inert salt", maintaining a practically constant ionic strength during the run. Aliquots were drawn from the agitated reaction flask. The drop in TZ^+ concentration was followed by gravimetric determination of the TZ^+ as the picrate; the OH^- was titrated electrometrically. The formazan yield was determined by spectral absorption at 480 mμ in 7 acetone: 7 n-butanol: 1 acetic acid: 10 aqueous aliquot. It was not possible to determine or even identify products other than triphenyl formazan.

Conclusions. The decomposition here studied should be considered as a potential side-reaction in the analytical uses of TZ^+ at or above 60° C.

It seems plausible that the decomposition of the TZ^+ occurs when an ion-pair, TZ^+OH^-, reacts with a second OH^- to form an unstable triple-ion, $TZ(OH)_2^-$. The irreversible decomposition (13) of this $TZ(OH)_2^-$, with release of one OH^-, is the rate-determining step. Assuming an equilibrium among the triple-ion and free ions, TZ^+ and OH^-, would lead to the observed orders in TZ^+ and OH^-. The observed *k* would be the product of the equilibrium constant for the ion-triplet formation from the free ions and the specific rate constant for the ion-triplet's decomposition (13). The formazan is probably produced in one of several consecutive or branching reactions and its formation is probably catalyzed at the surface of the colloidal particles of formazan.

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A STUDY OF LEG LENGTH VARIATIONS IN THE WOOD FROG, *RANA SYLVATICA* LE CONTE[1]

HOWARD K. SUZUKI[2]
Department of Biology, Marquette University
Milwaukee 3, Wisconsin

Schmidt ('38) made a study of the geographic variations in the leg lengths of some frogs, including *Rana sylvatica*, and found that there was a north-south gradient on leg length. The shorter-legged forms are distributed in the northern areas of North America, and the longer-legged frogs in the southern regions. *Rana sylvatica* Le Conte is comprised of two subspecies, *R.s. sylvatica* Le Conte and *R.s. cantabrigensis* Baird, which are classified by differences in body/tibia ratios. Wright and Wright ('49) give the ratio range for *R.s. sylvatica* as 1.67 to 1.88 and *R.s. cantabrigensis* as 1.93 to 2.30.

The northern subspecies range from Alaska, through Canada, southward into the northern half of Wisconsin and Michigan and eastward to the mouth of the St. Lawrence River. The southern subspecies extend from Southern Wisconsin eastward through the Midwestern and Eastern states, and northward into Southeast Canada (Wright and Wright, '49).

In order to clarify the status of *R.s. sylvatica* and *R.s. cantabrigensis* in Wisconsin, it was necessary to compare these forms with subspecies from other localities.

MATERIALS AND METHODS

Wisconsin specimens were obtained in a survey of Wisconsin amphibians (Suzuki, '51). In addition, Wood frogs from Wisconsin and other localities were borrowed and examined from the University of Michigan, University of Wisconsin, and Milwaukee Public Museum.

A vernier caliper was used to measure adult specimens for their body and tibial lengths. Body lengths were determined by measuring from the tip of the snout to the cloacal aperture. Tibial measurements were made by flexing the leg and taking the outside

[1] This investigation was carried out with a 1946 grant-in-aid from the A.A.A.S. received through the Wisconsin Academy of Sciences, Arts, and Letters.

[2] Present address: Department of Anatomy, Yale University School of Medicine, New Haven 11, Connecticut.

dimensions of the tibia. The ratios were analysed by the *t* test for statistical significance and Table 2 was adapted after the method of Dice and Leras ('36).

RESULTS

Variations in the body/tibia ratios of frogs from five localities are tabulated in Table 1. The mean ratios (x) range between 1.66 through 2.01, the former representing the mean of a southern Wisconsin population, and the latter an Alaskan group. Frogs from the other areas possess intermediate body/tibia ratios. There are no significant sex differences.

TABLE 1

VARIATIONS IN BODY/TIBIA RATIOS OF *RANA SYLVATICA*

LOCATION	NUMBER	SEX	x	S	2S	2(S$_{\bar{x}}$)
Alaska	51	♂	2.01	0.0958	2.01±0.1916	1.983–2.04
North Dakota	7	♂	1.93	0.064	1.93±0.138	1.86 –2.00
N-C Wisconsin	29	♂	1.78	0.108	1.78±0.216	1.74 –1.82
Maine	66	♂	1.72	0.062	1.72±0.124	1.70 –1.74
S Wisconsin	65	♂	1.71	0.070	1.71±0.14	1.692–1.728
Alaska	25	♀	2.00	0.0787	2.00±0.157	1.97 –2.03
North Dakota	14	♀	1.92	0.049	1.92±0.098	1.89 –1.95
N-C Wisconsin	74	♀	1.78	0.122	1.78±0.24	1.75 –1.808
Maine	18	♀	1.72	0.86	1.72±0.172	1.68 –1.76
S Wisconsin	11	♀	1.66	0.100	1.66±0.20	1.59 –1.73

x is the mean body/tibia ratios of the populations.
S is the standard deviation.
2S is twice the standard deviation.
2(S$_{\bar{x}}$) is the confidence inference which indicates that means of samples gathered from the specific areas will fall within the confidence inference range 95% of the time.

Very little overlap is noted in the relative range of leg length differences between the Alaskan and Maine and southern Wisconsin frogs, while North Dakota and northern Wisconsin forms have intermediate ratios (Table 2). There is a definite north-south gradient represented.

Thirty-three out of 76 frogs from Alaska, the northern form, have body/tibia ratios ranging from 2.00 to 2.05, whereas 30 out of 84 frogs from Maine, the northern form, have body/tibia ratios ranging from 1.71 to 1.76 (Table 3). Twenty-eight out of 76 frogs from southern Wisconsin are in the same body/tibia ratio range as those from Maine. Wood frogs from northern Wisconsin have body/tibia ratios that overlap the southern Wisconsin forms, but in addition have an almost equal number with higher body/tibia ratios (Table 3).

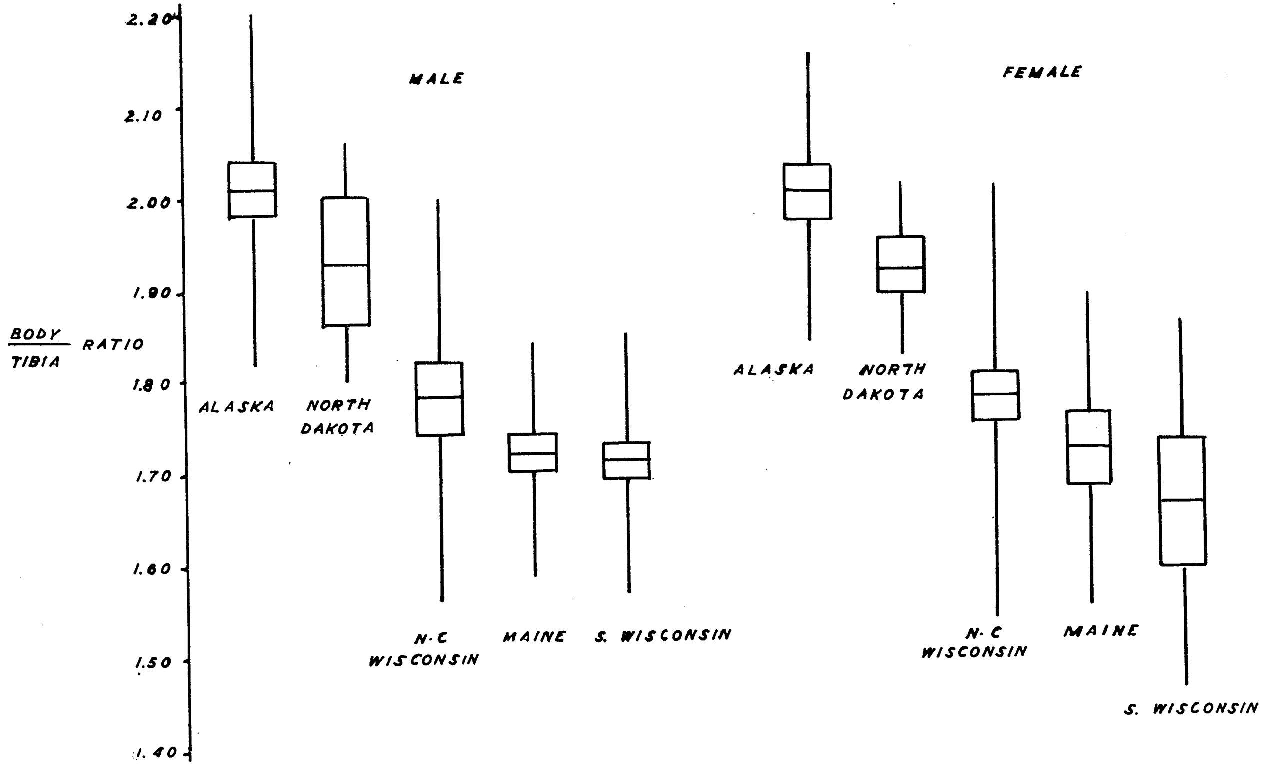

TABLE 2. A graph of the body/tibia ratios of *Rana sylvatica*. The length of each line represents twice the standard deviation. The middle cross-bar represents the mean. The two other cross bars are placed at the 95% confidence inference level above and below the mean forming a rectangle. If the rectangles do not overlap, then the ratios are considered to be significantly different. For example, the Alaskan and N. C. Wisconsin forms have significant differences in body/tibia ratios, while Maine and S. Wisconsin frogs do not have significant differences.

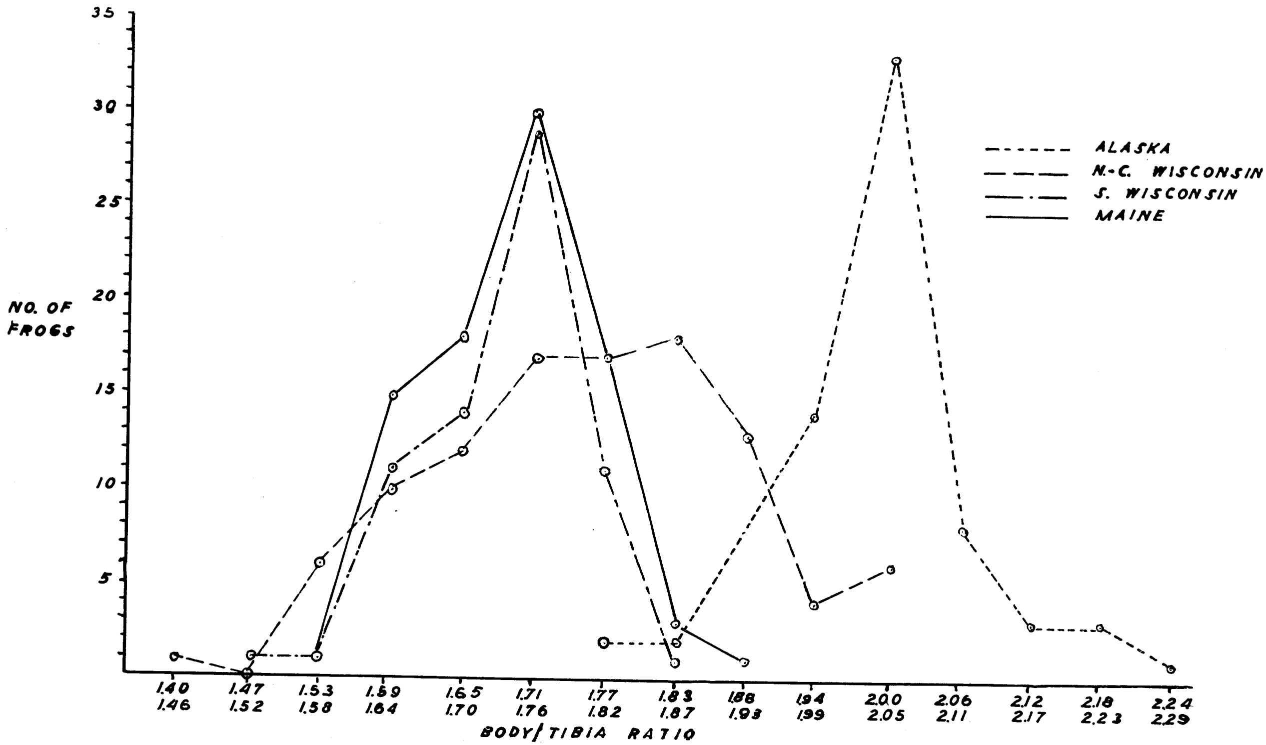

TABLE 3. Distribution of frogs within body/tibia ratios ranges. The Maine and southern Wisconsin populations have similar curves while the Alaskan frogs have much higher ratios. The N. C. Wisconsin frogs form an intermediate population with a more widespread distribution.

Discussion

There are no significant sex differences in body/tibia ratios in the individual populations. Differences observed are accounted for by the lack of sufficient numbers.

Frogs from southern Wisconsin and northern Maine have body/tibia ratios which are similar. Although frogs from northern Wisconsin were caught in an area in the same north latitude as those from Maine, the northern Wisconsin forms possessed shorter extremities. Therefore, *R.s. sylvatica* is found farther north in the eastern United States than in the midwest.

Frogs from North Dakota have shorter legs than those from northern Wisconsin. The North Dakota frogs were caught at Stump Lake which is 3° north latitude higher than those from northern Wisconsin. Alaskan frogs, the most northerly distributed population in this study, possessed the shortest extremities.

Therefore, there is a north-south gradient of the body/tibia ratios in *Rana sylvatica,* and substantiates the findings of Schmidt ('38).

Wisconsin presents a unique area for the study of Wood frogs, since this state seems to be an area of integration between the two subspecies. Further studies need to be carried out on this form in Wisconsin.

Conclusions

1. There are no significant sex differences in body/tibia ratios in *Rana sylvatica.*
2. Data has been presented to show that there is a north-south gradient of body/tibia ratios in the Wood frogs.
3. Although it is possible to distinguish *R.s. cantabrigensis* and *R.s. sylvatica* at their extreme ranges, at present it is not possible to distinguish the two in Wisconsin subspecies.

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THE EFFECTIVENESS OF EXPANDED ALUMINUM FOIL IN PREVENTING RABBIT DAMAGE[1]

ROBERT A. MCCABE and LLOYD B. KEITH
Department of Forestry and Wildlife Management, University of Wisconsin

The cottontail rabbit *(Sylvilagus floridanus)* is an abundant native Wisconsin mammal. It thrives in both urban and rural areas. The crucial time of year for cottontails comes during severe winter weather. Although rabbits are seldom in need of cover, their food supply may be sharply reduced by a blanket of snow. When green or cured herbage becomes unavailable, rabbits feed on the bark of young trees and shrubs. In the process, twigs are clipped and trees are often girdled, resulting in great economic loss to home-owners with landscaped grounds, to orchard men, nursery men, forest interests, and farmers. This loss and the efforts made to prevent it are known in Wisconsin as the "rabbit problem."

Control of rabbit damage is achieved either by eliminating the rabbits or protecting valuable plants. Often a combination of methods is employed, but in most cases complete control is seldom realized. In urban areas where the plants needing protection are sufficiently valuable to warrant individual care, mechanical devices and repellents are used.

The object of this report is to present the results of tests run on a newly-developed protective screen designed to discourage rabbit damage. It is sold commercially as "Rabbit-rap" and is manufactured exclusively by the Research Products Corporation of Madison, Wisconsin. The material is expanded .003-gauge aluminum foil. The expansion cuts are $\frac{7}{16}$ inch in length, and eight cuts are made per 14 inches. This pattern produces the mesh shown in Figure 1. This material has the following advantages as a protecting wrapper for trees and shrubs: (a) it is light in weight and easy to handle; (b) it can be cut with pocket knife or a pair of scissors; (c) it is pliable and can be bent, twisted, or folded with bare hands; (d) it is expandable so will not injure the plant by constriction; (e) it needs no special supports or ties to keep it in place; (f) it is easily applied, removed, and stored.

The salient criterion for any such material, however, is: does it prevent rabbit damage? Uncontrolled trials were run on some of

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[1] Journal Paper No. 37, University of Wisconsin Arboretum Series.

the horticultural plantings on the University Arboretum for several years and indicated that the wrappings were successful.

In the winter of 1956–57 we ran a series of field trials on the University-owned Picnic Point Wildlife Refuge (Madison, Wisconsin). The winter was below average in snowfall, but was below normal in temperature. The rabbit population was about average for the past ten years. In any event, the weather was severe enough and the rabbits plentiful enough to conduct the trials satisfactorily.

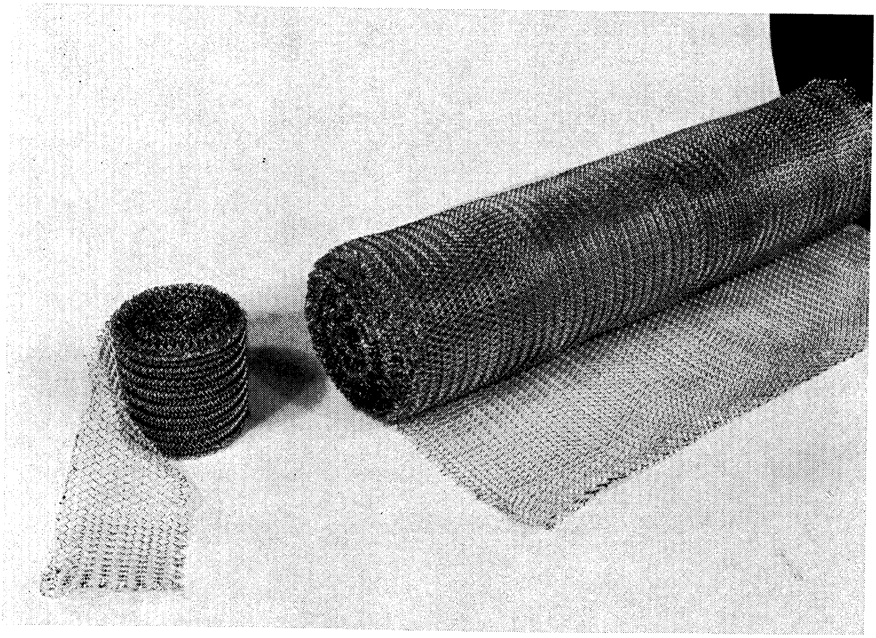

FIGURE 1. Rabbit-rap in 4-inch and 28-inch mesh; only two widths are available commercially.

TRIAL ONE

In order to subject the wrapping material to the severest possible test, we gathered a number of large limbs pruned from trees in the University apple orchard, to be used as the protected woody plant. Apple is known generally as a plant high on palatability lists (Sweetman, 1949; McCabe, 1947). These limbs with their numerous twigs were wrapped with the expanded foil which was cut into foot lengths.

A foot of wrapped bark alternated with the foot-long exposed segments. When wrapped, these limbs were laid on the ground under the pines in a large grove known to be frequented by cottontails. This group of limbs remained in the pine grove for 14 days during which it was checked every three to four days. The exposed bark was completely eaten, and some damage to the protected stem was evident after the second night. The situation became progressively worse throughout the 14-day test. Both large (2 inches in diameter) and small twigs were badly damaged in spite of wrapping. In most cases, the rabbits chewed through the foil mesh to get at the bark (Fig. 2). In a few instances the edges of the wrapping adjacent to the exposed sections were rolled back apparently by nuzzling.

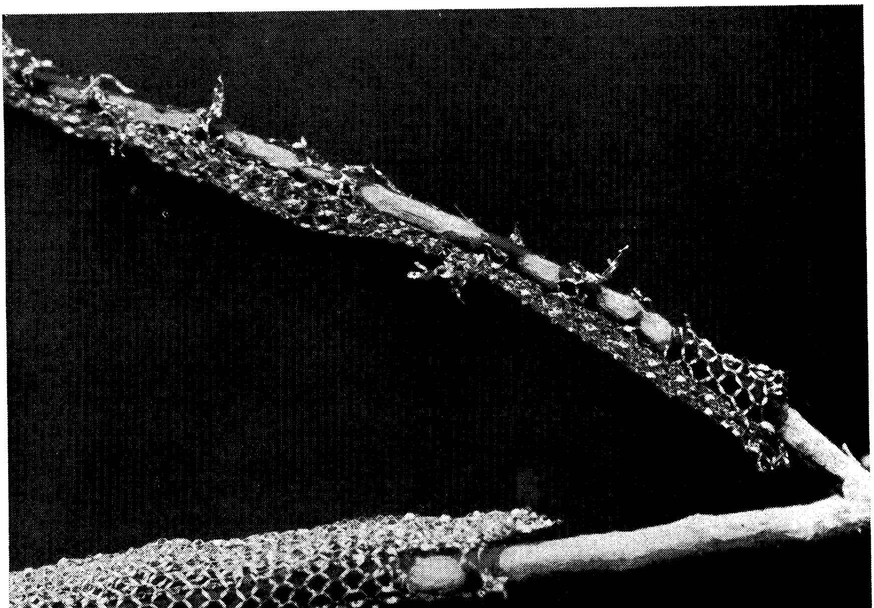

FIGURE 2. Cut apple twigs ¼-inch in diameter covered with Rabbit-rap which rabbits chewed through to get at the edible bark.

A second run was made in this trial using fresh cuttings but the material set in the same place was allowed to remain in the field for only one week. The results of this run were only slightly better than those of the 14-day test period.

In the third run, a wrap of large-sized mesh of the same gauge foil was used. This material is used to manufacture another product but was tried because it appeared rougher than the Rabbit-rap mesh. The experimental conditions were the same as in the two previous runs. The results, however, were considerably better than those obtained from either of the tests using the standard Rabbit-rap. A comparison of the three runs in first trial is shown in Table 1.

TABLE 1

DAMAGE TO "RABBIT-RAPPED" APPLE BRANCHES

Material	Test Time	Wrapped Branches (ft.)		Control (ft.)	
		Length	Damage	Length	Damage
Rabbit-rap	14 days	65	30.5 (47%)	72	72 (100%)
Rabbit-rap	7 days	45	18.1 (40%)	43	43 (100%)
Large mesh	7 days	45	10.3 (23%)	58	58 (100%)

It is clear from the table that the bulk of the damage occurring on the test wrappings took place during the first week. The large mesh foil appears to be about twice as effective as Rabbit-rap itself. In all cases, the controls were completely browsed.

This trial is somewhat artificial in that the plants to be protected were cut and placed in sheltered areas of high rabbit use. The plants were also laid flat on the ground, although some branches simulated the normal upright growing position. The tests did show that (a) the rabbit is both willing and able to bite through the metal covering, and (b) that the metal clippings are not ingested. They are instead scattered over the ground in the area of the browsing and none were found in the droppings.

Another similar test was made by Don W. Hayne of Michigan State University (pers. comm., May 16, 1957) who covered fresh carrots with Rabbit-rap and placed them in a cage with field mice (*Microtus* sp.). Like the rabbits in trial one, the mice chewed through the wrapping to get at the carrot.

In both cases, the experimental conditions were not strictly comparable to field situations.

Trial Two

A field test was set up using live and growing woody plants. A single large clone of smooth sumac *(Rhus glabra)* of about 125 stems 3 to 7 feet in height and ¼ to 1 inch in diameter was selected (Fig. 3). Rabbit-rap was placed around the base of 25 of these shoots. Those remaining unwrapped were to act as controls.

Although sumac is high in palatability ratings for rabbits, this clone was on a side hill and not adjacent to good rabbit cover. Thus during severe weather when damage is likely to occur, this area was not heavily used by cottontails. In the spring, when the final check on this trial was made, 62 per cent of the 98 unwrapped shoots was damaged by rabbit browsing. None of the wrapped stems was damaged, nor was the wrapping molested. The likelihood of differential palatability or availability was nil since the wrapped stems were selected at random (every fifth stem moving west through the clone) and the clone is in effect a "single" plant. There was no mouse damage to these shoots, and there was no mouse sign in the area. It appears from trial two that with relatively light usage by rabbits under natural conditions the wrapping material was completely effective.

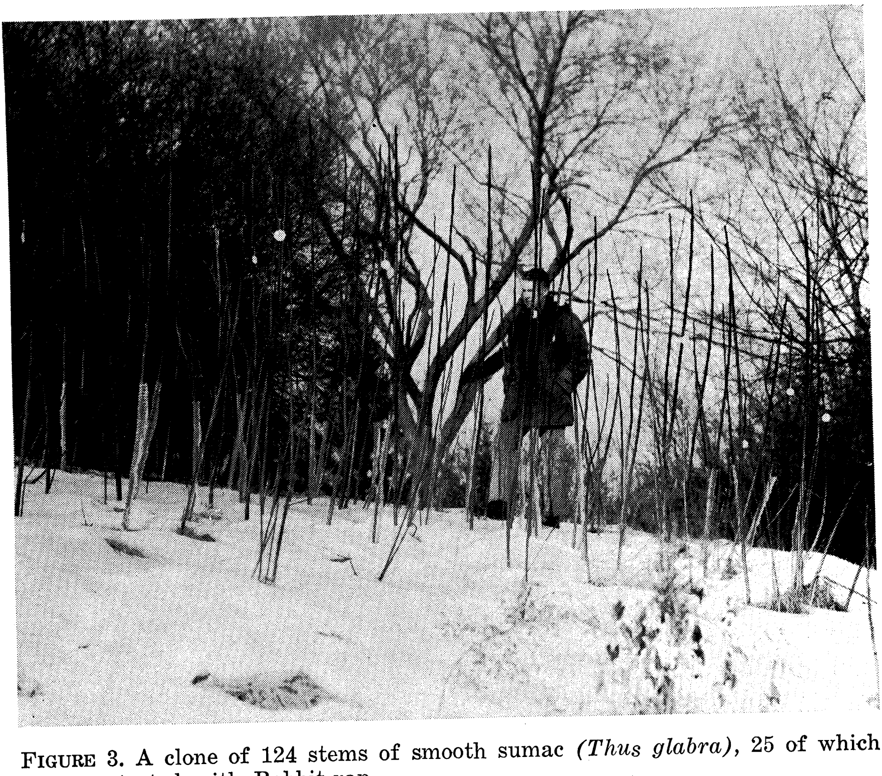

FIGURE 3. A clone of 124 stems of smooth sumac *(Thus glabra)*, 25 of which were protected with Rabbit-rap.

TRIAL THREE

Another location in the same general area was used to check Rabbit-rap in a site of high rabbit use. A stand of staghorn sumac *(Rhus typhina)* that has for years been subjected to severe rabbit browsing, was selected. In this stand, tender shoots less than one-year old were grouped in pairs, one of which was wrapped and the other to act as a control. Twenty-five pairs were so treated. Damage to all unwrapped shoots began with the onset of inclement weather. By spring all unwrapped shoots (over 300) were badly browsed including those of the experimental pairs which were unwrapped (Fig. 4). No damage resulted to the protected stems. Thus a second test under natural conditions, using a plant species of high palatability and ready accessibility and in an area with an abundance of rabbits, showed the wrapped stems to be 100 per cent protected and the controls completely damaged.

FIGURE 4. Severe damage to the unwrapped member of a pair of staghorn sumac *(Rhus typhina)* shoots.

TRIAL FOUR

A multibranched bush is difficult to protect and at the same time is no less vulnerable to rabbit browsing. On the Picnic Point refuge is an old spiraea hedge *(Spiraea Vanhouttei)* which, like the sumac in trial three, has been cropped back by rabbits (Fig. 5) each year for many years. Two clumps of this shrub were wrapped with the protective foil. They were separated by a clump which was left unwrapped, along with about twenty similar clumps in the hedge which were to act as controls. Here, too, rabbit damage occurred very early in the winter and became progressively worse. By April *all* unwrapped clumps were cropped back to about a foot above the ground. The two wrapped clumps suffered no damage (Fig. 6) nor was the protective mesh damaged. The conditions of this test are comparable with conditions that occur in sites landscaped with ornamental plantings.

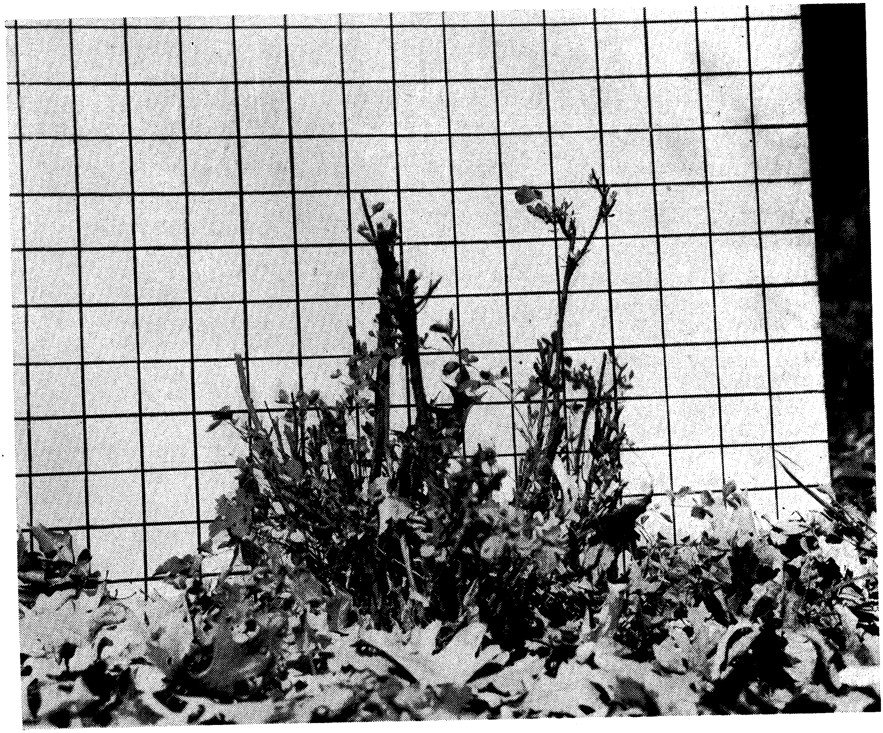

FIGURE 5. A clump of Spiraea *(Spiraea Vanhouttei)* that has been browsed back by rabbits each year for at least 10 years.

DISCUSSION

The failure of Rabbit-rap to deter browsing on a mass of apple branches or to prevent mice from gnawing a wrapped carrot would seem to indicate that the wrapping was ineffective. The test situation in both cases was unlike field conditions for which the protective material was designed. However, it does show that the two animals most likely to injure a tree by eating its bark are physically capable of gnawing the expanded aluminum foil. Analysis of field situations point to the roughened condition of tree bark as discouraging rabbit browsing (McCabe, 1947). It is this aspect of normal

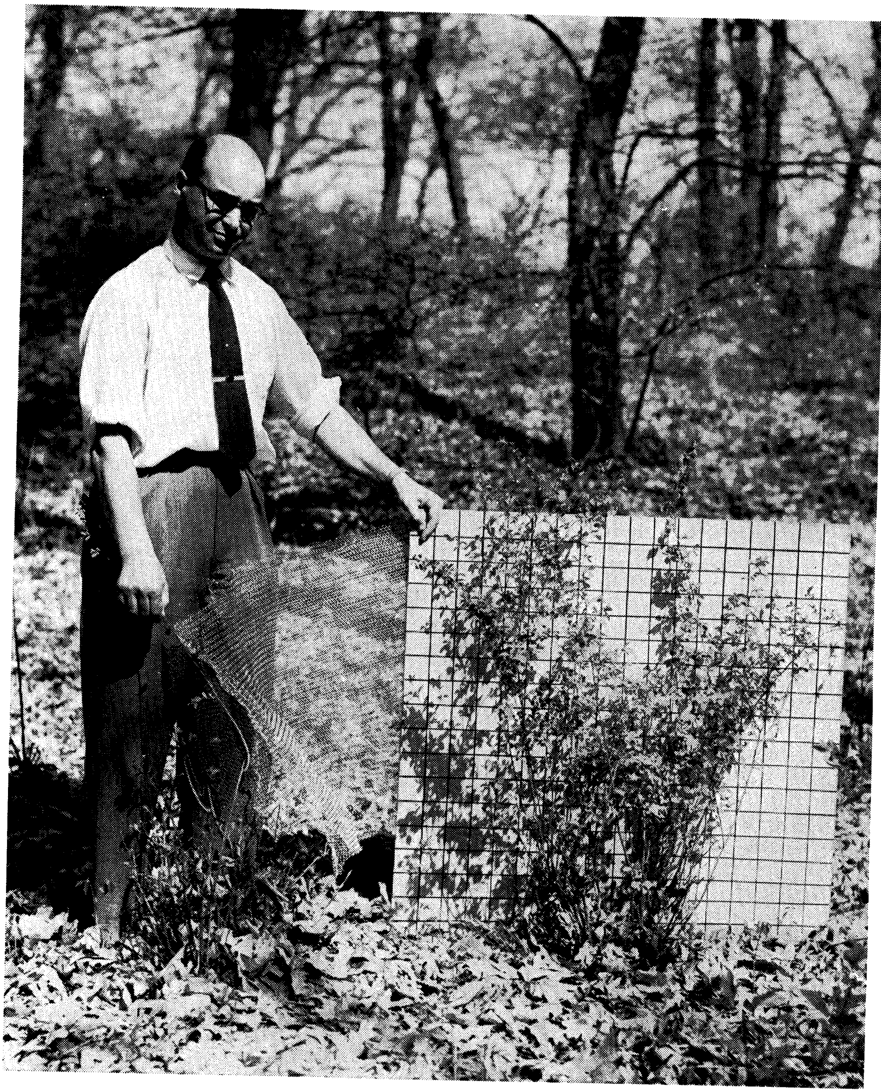

FIGURE 6. A spiraea *(Spiraea Vanhouttei)* bush protected by Rabbit-rap for only one winter.

growth that was being simulated in the foil wrapping. Even normally roughened bark of mature trees is occasionally gnawed under conditions of severe food shortage.

The greater effectiveness of the larger mesh pattern over the standard Rabbit-rap mesh suggests a change in pattern for Rabbit-rap for maximum effectiveness.

Just how a rabbit recognizes the palatable bark on woody plants is not known, but odor and trial and error browsing seem from field observation to be the likely methods. The care with which a rabbit sniffs a twig before biting into it indicates that the aroma from bark is not strong. If the protecting material is wrapped loosely it will keep the rabbit nose at a safe distance and will prevent the animal from cutting both metal and bark in a single bite.

Field tests of uncut woody plants of high palatability showed the protecting foil to be 100 per cent effective. These test conditions were similar in most respects to those under which Rabbit-rap should be used. The test plant *Spiraea Vanhouttei* is an ornamental in common use which often needs protection from rabbits. It seems that many ornamentals are particularly susceptible to browse damage (McCabe, 1947). The effectiveness of Rabbit-rap against mouse attack was not investigated.

The present cost of Rabbit-rap protection is about 20 cents for a tree three inches in diameter, wrapped to a height of two feet. Large quantities of the material would doubtless reduce the cost. It takes from two to five minutes to wrap a tree under snowless conditions. In the spring shoots of herbaceous plants such as tulips and jonquils can be protected by Rabbit-rap until other greens become available as rabbit food.

If handled with care, the foil may be removed, stored, and reused in subsequent years.

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Summary

Four trials were set up to test the effectiveness of expanded aluminum foil (commercially known as Rabbit-rap) as a protecting screen for woody plants against gnawing by rabbits. All tests were run from January through March, 1957. Trial one, using cut apple stems placed in an area of high rabbit density showed that over a 7- and 14-day period the damage to "protected" trees was 40 and 47 per cent respectively. A similar material (not sold commer-

cially) of a larger mesh under the same test conditions showed 23 per cent damage to wrapped stems.

In trial two on a single clone of smooth sumac where 25 stems were wrapped and 98 left unwrapped as controls, none of the wrapped stems was injured and 62 per cent of the controls was damaged. The rabbit use of the area was light.

Trial three has one stem of 25 paired samples of staghorn sumac wrapped and the other as an unwrapped control. The wrapped stems were 100 per cent protected and the controls 100 per cent damaged over the three-month period.

Trial four on an ornamental shrub *(Spiraea Vanhouttei)* showed two wrapped clumps completely protected and the remaining clumps (15–20) without exception, were damaged.

Although rabbits were capable of gnawing through the expanded aluminum foil in an artificial situation, under natural field condition Rabbit-rap was highly satisfactory.

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