# Transactions of the Wisconsin Academy of Sciences, Arts and Letters. volume XXXV 1943

Madison, Wis.: Wisconsin Academy of Sciences, Arts and Letters, 1943

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# TRANSACTIONS

OF THE

# WISCONSIN ACADEMY

OF

## SCIENCES, ARTS AND LETTERS

VOL. XXXV

NATURE SPECIES RATIOQUE

MADISON, WISCONSIN

1943

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TABLE OF CONTENTS

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# THE PRAIRIE CHICKEN AND SHARP-TAILED GROUSE IN EARLY WISCONSIN

BY A. W. SCHORGER

Some of our most interesting and formerly abundant game birds have reached extinction or now maintain precarious existance. The subjects of this paper, the prairie chicken (*Tympanuchus cupido americanus*) and the sharp-tailed grouse (*Pedioecetes phasianellus campestris*), were so abundant a century ago as to play an important role in the realms of food and sport. As remarked by W. W. Cooke,[1] who came to Buffalo County in 1856: "Of the prairie chicken and grouse family, what an abundance nature furnished us!" Today the sharp-tailed grouse is in no danger of extinction, thanks to suitable habitat, but the prospect for the prairie chicken is by no means hopeful for the distant future.

The investigation of the status of the two species of grouse in Wisconsin in the early days was initiated in the belief that the history of any species has intrinsic value. The main objective, however, was the hope that information might be drawn from the study that would aid in increasing the population beyond the point of danger, or indicate the probable futility of the effort.

## PART I. THE PRAIRIE CHICKEN

*Original Range.* The determination of the range of the prairie chicken or pinnated grouse prior to settlement for agricultural purposes is extremely difficult. Accuracy is not possible for several reasons. The sharp-tailed grouse occurred throughout the state and is so similar in appearance to the prairie chicken that no distinction was made by the casual observer even in the southern portion of the state where their ranges overlapped. Few trained observers visited the state and even their statements are occasionally of doubtful accuracy. Another difficulty was the relatively slight difference in habitat and habits. The prairie chicken was called locally "prairie chicken," "prairie hen," "grouse," "moor-hen," and "whirring pheasant." The latter name was used by the early French inhabitants.

The inclination to fix the original northern range of the prairie chicken below its probable limit in the upper Mississippi Valley is due largely to Coues.[2] He was informed by Dr. J. F. Head that, in 1853, the prevailing if not the sole grouse in the vicinity of Fort Ripley (Crow Wing County) was the sharp-tailed grouse; and that the first pinnated grouse was killed in September, 1873. While these observations were accurate prob-

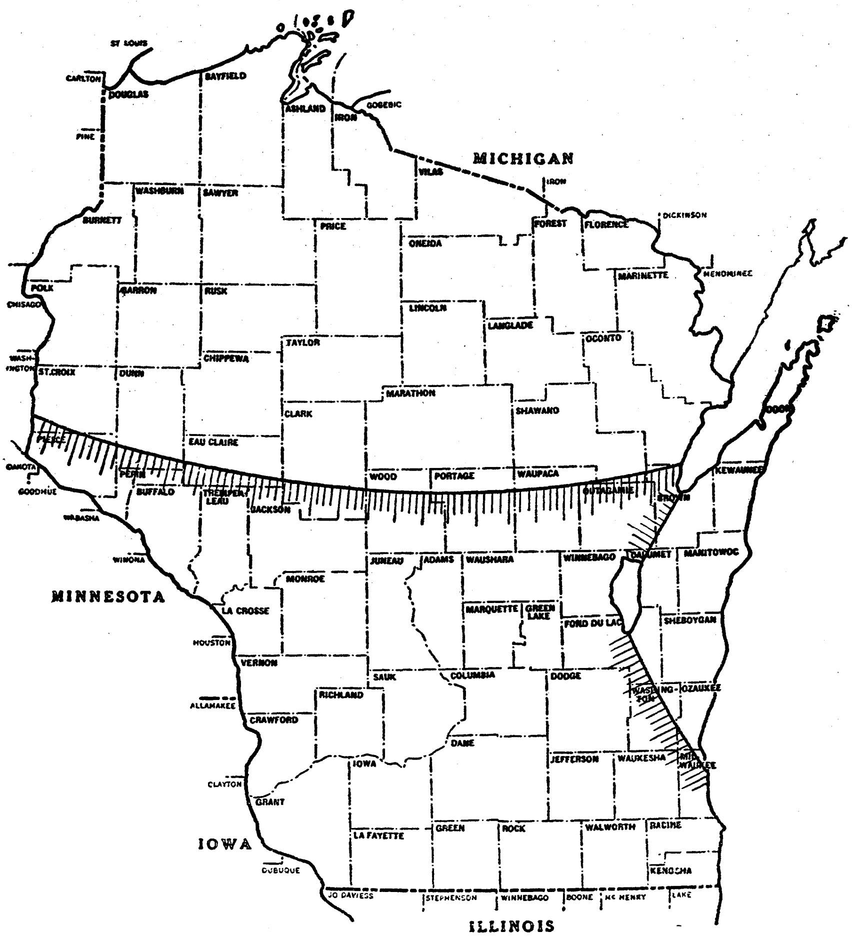


Fig. 1. Probable original breeding range of the prairie chicken in Wisconsin.

ably for that particular locality, it cannot be inferred that the prairie chicken was absent from the prairies of southern Minnesota.

Against this statement may be placed that of "Raven"[3] who hunted in Minnesota in the fall of 1860: "After leaving St. Cloud, which is seventy-five miles northwest from St. Paul, along the valley of Sauk River we began to find the sharp-tailed grouse; and farther west they became still more abundant, while the pinnated nearly disappeared."

The situation in Wisconsin was quite similar. T. S. Van Dyke[4] followed the prevailing opinion that in the early days in Minnesota and Wisconsin the sharp-tailed grouse was the common bird of the prairie while the prairie chicken was seen rarely; and that agriculture brought about a complete reversal. With commendable caution, however, he adds that it is uncertain if the increase of the prairie chicken was "actual or apparent." Thure Kumlien, in 1840, found the sharp-tailed grouse to be the common grouse of the prairies and was very abundant in southern Wisconsin. He resided in the state several years before seeing a specimen of the prairie chicken.[5] There is little evidence that he was familiar with conditions outside the vicinity of Lake Koshkonong, hence the opinion should be considered of local value only.

The first incontestable record of the prairie chicken in the Lake Michigan area, and in fact the first definite description of the species, is due to Marquette.[6] He spent the hard winter of 1674-75 on the present site of Chicago. His man Jacques shot a "partridge" having two tufts of feathers, as long as a finger, on the sides of the neck where there were bare spots.*

In travelling up the Illinois River in August, 1821, Schoolcraft[7] flushed the "prairie hen or 'whirring pheasant'." Ten years later in crossing the prairies of southern Wisconsin from Galena to Fort Winnebago, Wisconsin, he[8] was "often startled by the flocks of the prairie-hen rising up in his path."

Southwestern Wisconsin was visited by General Smith[9] in 1837. Here he found the prairie chicken very numerous. The

* "Jacques apporta un perdix qu'il avoit tuez, semblable en tout a celles de France, excepte qu'elle avoit comme deux aislerons de 3 ou 4 aisles longues d'un doigt proche de la teste, dont elles couvrent les 2 costez du col ou il n'y a point de plume."

reason for assuming that this was the pinnated grouse is his belief that it was identical with the "Long Island grouse" (heath hen). Charles Rodolf,[10] in 1834, settled at the present site of Wiota, Lafayette County. At that time he found game abundant: "grouse [sharp-tailed], prairie chickens [pinnated], pheasants [ruffed grouse], quails."

The prairie chicken, according to Hoy,[11] and Barry,[12] was abundant in the Racine region in the early '50s. There is good evidence that it was numerous prior to the time when agriculture could have been a determining factor. Quarles[13] wrote from Southport (Kenosha) on August 28, 1838: "It is 3 years since the first settler came in. . . . Prairie hens are very plenty —They resemble a pattridge [ruffed grouse] but have short tails and are much larger." Also, Burch[14] wrote from Southport, in 1842, that "prairie hens" were plentiful.

The northern range of this grouse on the prairies bordering the Mississippi is not determinable easily. Hoffman,[15] while in Illinois, called the pinnated grouse both prairie hen and grouse. On February 12, 1834, he wrote from Prairie du Chien: "The grouse now keep in large packs near the garrison." The prairie at Prairie du Chien at that time was virtually a large common. The great winter assemblages were characteristic of the species.

Bunnell[16] came to Trempealeau in 1842. In September of the following year, he went up the Trempealeau River to hunt elk on Elk Creek, on the "prairie slopes" of which he killed some "pinnated grouse." This statement is not so convincing when it is considered that in his list of the birds of the region, only the pinnated grouse is mentioned. The sharp-tailed grouse was certainly present also and probably more numerous. At the time of Bunnell's arrival, James Reed was settled at Trempealeau. Grignon[17] says of Reed: "I have seen him kill eleven prairie chicken in twelve shots, in the trees on the island across from Trempealeau."

At La Crosse,[18] in the fall of 1857, it was considered noteworthy that prairie chickens were scarce that season east of the Mississippi, but plentiful forty miles west of it in the neighborhood of Chatfield, Minnesota. In 1859, 75 prairie chickens were purchased at La Crosse, the birds having been killed in the "openings" above Bangor.[19] Prairie chickens were abundant at La

Crosse[20] in 1861, and in October were *migrating* over the town. The October migration also was characteristic of the species.

The pinnated grouse was in Pierce County at least by 1856 for it is stated in that year: "Pheasants [ruffed grouse], grouse [sharp-tailed], and chickens [pinnated] are also very plenty."[21] In 1855, "prairie chickens" were plentiful and cheap at Hudson, St. Croix County.[22]

There was an abundance of the "prairie chicken and grouse family" at Gilmanton, Buffalo County, when Cooke[1] settled there in 1856. Cartwright[23] hunted on the Red Cedar River in the fall of 1857. One day a companion shot "a big pile of prairie chickens and partridges."

The prairie region of central Wisconsin appears to have been inhabited by pinnated grouse since the advent of settlement. Hoyt's[24] map of 1861 shows a strip of prairie extending to the bottom of Green Bay and along the western shore. Biddle[24a] states that the prairie hen was abundant at Green Bay in 1816. While at Green Bay in August, 1834, Bishop Kemper[25] was presented with a wild goose and a "prairie hen." Col. Whittlesey[26] travelled from Green Bay to Galena, Illinois, in 1832. In passing up the Fox River his "path generally lay through a wild pasture, well stocked with the prairie hen." South of Portage he "started a plenty of grouse."

In the autumn of 1835, Featherstonhaugh[27] was at Fort Winnebago (Portage) and in the course of a walk flushed "several very large grouse (*Tetrao cupido*)." This statement would be highly satisfactory were it not for the fact that later in the autumn he found grouse abundant along the Minnesota River and considered them to be *Tetrao cupido*. They rose "booming and screaming." It has been my experience that the sharp-tailed grouse is the noisier of the two species when flushed. In May, 1836, he returned to Wisconsin and in the vicinity of Blue Mounds frequently flushed the "prairie hen" from her nest.

In 1840, Haraszthy[28] travelled from Madison to Lake Winnebago and wrote: "While crossing this marvellous region . . . . thousands upon thousands of prairie chickens, partridges, and pheasants flew up before us continuously, and we needed all such game for this area is unsettled, and we were obliged to get our food with guns."* Richard Dart's family was the first to settle

* Mr. Kliman, the translator, informs me that it is impossible to translate more accurately the Hungarian names of the birds, *vadtyuk*, *fogoly*, and *faczan*. *Vadtyuk* means litterally marsh or moor hen.

in Green Lake County. Prairie chickens were plentiful when he arrived in 1840.[29] Their boat was pulled by error into Rush Lake. In order to make camp it was necessary to wade the broad marshes during which procedure they saw flocks of ducks and "prairie chickens."

Captain Mackinnon[30] hunted at Lake Winnebago in 1851. He did not shoot the "vast prairies" on the western side of the lake that he considered must be swarming with grouse; however, he stated that he had no difficulty in killing as many as he desired regardless of the direction chosen. He made this significant statement: "The few settlers who have recently taken up land on these wild meadows, complain much of the increase of grouse. It is indeed a singular fact, that game increases rapidly with the first settlement of a new country. When, however, the population arrives at a certain point, the game as rapidly decreases, and often in America disappears altogether." Proof of the presence of the prairie chicken is found in a statement of the same year for the vicinity of Oshkosh: "Grouse and prairie chickens are superabundant."[31]

*Habits.* There are few if any habits that distinguish sharply between the two species of grouse. The prairie chicken in the west was found most frequently in the grasslands and the sharp-tailed grouse in brushy areas and oak openings. Wilson[32] quotes Dr. S. L. Mitchell extensively on the habits of the heath hen, a very close relative of the prairie chicken, on Long Island. The latter at the time was largely a bushy plain. He states: "On frosty mornings and during snows, they perch on the upper branches of pine-trees. They avoid wet and swampy places; and are remarkably attached to dry ground. The low and open bush is preferred to high shrubbery and thickets. Into these places, they fly for refuge when closely pressed by the hunters . . ."

The Kentucky "barrens" in which the prairie chicken once occurred abundantly was a brushy area, the name connoting merely the absence of large trees. Michaux,[33] who passed through the region in 1802, found it clothed with grass two to three feet high and small trees. Another traveller[34] describes the cover as hazel brush, grass, and small trees.

The perching habit is well developed in both species of grouse.

Audubon[35] remarks on the prairie chicken flying across the Ohio River and "alighting at once on the highest trees with as much ease as any other bird"; and that during severe weather it was known to roost at a considerable height in trees. Blane[36] considered the "prairie fowls" to be very similar to the Scotch grouse, but differing in the singular respect that when flushed they would alight upon a fence or tree, if available. In the winter of 1849-50, Marsh[37] shot many prairie chickens in De Kalb County, Illinois. They alighted frequently on the house, the straw roof of the prairie stable, and the fence of the cow-yard. In 1849, John Muir[38] came to Kingston, Green Lake County, Wisconsin. He mentions that about sundown the prairie chickens flew to roosting places in the tall trees. This species had the singular habit in autumn of alighting on telegraph wires, at Boonesboro, Iowa, sometimes in great numbers.[39] Incidentally, when telegraph wires were first installed in the Chicago area, prairie chickens were killed frequently by striking them. Five birds from one flock were killed in this manner.[40]

It is evident that the perching trait was about as well developed in the prairie chicken as in the sharp-tailed grouse.

The heath hen is stated to have avoided wet situations.[32] This trait is not pronounced. More recently, Johnson[41] mentions "their known dislike to marshes or places that are naturally wet," but that at the present time they are forced to use them to some extent. On the other hand, Newell[42] states that when northwestern Iowa was first settled they nested in the sloughs as well as upon the uplands. Dart,[29] in 1840, in wading through the muddy marshes surrounding Rush Lake, flushed prairie chickens. In 1844, the birds were not as plentiful as usual on the low prairies in the immediate vicinity of Chicago, but were obtainable on the higher ground in any quantity.[43]

Both species resort frequently to damp situations. Schurz,[44] hunting near Watertown in August, 1855, had no success until evening when a "wet tract" was reached. In the fall of 1868, at Fond du Lac,[45] prairie chickens were scarce except near streams and woody coverts, only a few being found in open ground. It is not uncommon at the present time to find them using a booming ground where there is standing water.

*Migration.* The migration of the prairie chicken was formerly a regular phenomenon. Audubon[35] mentions that during severe winters the flocks at Henderson, Kentucky, were increased by others that "evidently came from Indiana, Illinois, and even from the western side of the Mississippi." Woods[46] wrote that these birds visited Gallatin County, Illinois, in the winter but went north in summer. It is also stated by Thomas[47] that the species was seen rarely in the region of the lower Wabash River in summer but was very common in winter.

Writing of the migration of the prairie chicken in Iowa, in 1888, Cooke[48] states that large flocks migrated in the fall from southern Minnesota and northern Iowa to southern Iowa and northern Missouri. He was the first to mention that only the females migrate. There are insufficient data to permit acceptance of differential sex migration as a general law. It is difficult to determine the distances migrated. The evidence is for a limited shifting of the entire population southward. The territory left by the birds that crossed the Ohio River was occupied probably by the birds immediately to the northward, the movement continuing step-wise to the limit of the northern range.

It is to be expected that the migration would be most noticeable in the northernmost region. As a matter of fact this migration was recognized at a comparatively early date in Wisconsin. In 1856, it was stated for the Milwaukee[49] region: "We have seen in early winter, thousands in a pack, when, for some days before, we had not met a single bird." In connection with the destruction of eggs and young by wet weather in spring, the writer remarks pertinently: "Then however, the damage is repaired to the general stock by the advent of whole colonies of old birds in the spring, from somewhere South. We believe that many leave here after the first frosts and go farther south, and we know that in the spring they come from the South, sometimes in very great numbers, to prepare for breeding."

In March, 1853, a flock of ten prairie chickens flew over East Water Street, Milwaukee,[50] travelling west. Just twenty years later they were flying over Racine.[51] Major Tenney,[52] who came to Madison in 1845, repeatedly shot prairie chickens on the Capitol Square. It is probable that these were migrating birds since most of the present site of Madison was originally heavily wooded.

The fall migration usually took place in October. Two are recorded for La Crosse. For 1861, we read: "Every morning hundreds of fat prairie chickens are flying over and through the city, affording fine sport for our gunners. This morning one of our neighbors shot four from his wood pile as they flew over."[53] Again, for 1863: "Prairie chicken . . . are very plenty in the city now. Every morning hundreds of them are flying about, skimming along over barns, darting past the house doors and alighting on garden fences. This morning we should think at least fifty men within the city limits were out with shot guns, popping away right and left, bringing a bird nearly every shot."[54]

The movement in this region was to the southwest. Webster[55] mentions that it is generally recognized that many of the prairie chickens that winter in Iowa, come from Wisconsin, Minnesota, and the Dakotas. Another writer[56] states that while a large number wintered near Fort Dodge, Iowa, they left in spring for Minnesota and Wisconsin.

It was not uncommon for the birds to alight on buildings in town during the fall migration. On October 9, 1871, one alighted on the roof of a store in Menomonie.[57] Six perched on the ridge of the German M. E. Church in Madison on October 27, 1879.[58] In November of the same year, prairie chickens were flying about the streets in Janesville. It was recognized generally that cool or cold weather induced the fall migration and a considerable shifting of the winter residents. In January, 1873, during a period of cold weather, very large flocks of prairie chickens flew over Eau Claire[60] for several days.

*Food.* There are relatively recent studies of the food habits of the prairie chicken, but no one seems to have investigated the subject on the virgin prairies. Legumes, some of which thrive best under annual burning, and other plants, typical of the prairie and its margins, that produced seeds of potentially high food value were:[61]

Wild Pea (*Lathyrus*), various species
Wild lupine (*Lupinus perennis*)
Psoralea (*Psoralea esculenta*)
Lead-plant (*Amphora canescens*)
False indigo (*Amphora fruticosa*)
Prairie-clover (*Petalostemum candidum*; *P. purpureum*)

Trefoil (*Desmodium acuminatum; D. canadense*)
Ragweed (*Ambrosia artemisiaefolia*)
Sunflower (*Helianthus*), various species
Climbing false buckwheat (*Polygonum scandens*)
Compass-plant (*Silphium laciniatum*)
Prairie dock (*Silphium terebinthinaceum*)
Acorns (*Quercus*) various species

Of the above plants, only the seeds of *Ambrozia* and *Polygonum* would be available in quantity when snow covered the ground.

The scarcity of prairie chickens at Fond du Lac[62] in 1867 was attributed to the eating of potato bugs by which they were poisoned. This curious opinion prevailed for several years. The Milwaukee *Herold* (March 20, 1873) published a letter from New Ulm, Minnesota, in which the writer stated that he had examined the crops of prairie chickens. Grain was absent, but they were filled with potato beetles and the seeds of *Chenopodium ambrosioides.*

The food problem was not so simple in winter and there has been considerable justifiable speculation on what the prairie chickens subsisted. Audubon[35] mentions that they alighted on the trees along the margins of the large rivers to eat grapes, and the leaves and berries of the mistleto. He also saw them alight in such numbers on the tops of sumach bushes, to eat the seeds, that the bushes were bent by their weight. The wild grape grew in great abundance in Wisconsin, particularly on the islands and banks of the Mississippi and other streams. The sumach was also common.

During severe weather when snow covered the ground and rendered most seeds unavailable, the prairie chicken resorted to budding. Schmidt[63] states it was thought at first that the prairie chicken did not bud extensively in Wisconsin, but that more recent observations show that they eat buds and catkins throughout the winter. Audubon[35] mentions damage to fruit trees in winter by the birds feeding upon their buds: "I have counted more than fifty on a single apple tree, the buds of which they entirely destroyed in a few hours."

In the winter of 1827-28, Fonda[64] carried the mail from Green Bay to Fort Dearborn (Chicago). Leaving Milwaukee, he and his companion turned west to the Des Plaines River. It was the month of January and he states: "This led through wide prairies and some large groves. Grouse were to be seen budding on the trees and we killed abundance of them as we passed along. The grouse with now and then a fish caught in the shallow rapids, formed our only food for several days." Presumably these were pinnated grouse for he mentions subsequently the preparation of "a couple of grouse (prairie-hens) for supper."

It is stated by Muir[38] that, in Green Lake County, the prairie chickens fed in the cornfields until the snow came, then they ate the buds of birch and willow. In December, 1872, they were eating "poplar" buds in Polk County,[65] and during the severe winter of 1874-75, "pinnated grouse" fed on poplar buds at Montello, Marquette County.[66] In March, 1883, they were eating birch, elm and other buds in the swamps near Dodgeville.[67]

The problem of the winter diet of the prairie chicken was investigated recently by Hamerstrom.[68] The logical conclusion was reached that the species can subsist on a diet of low nutritive value; and that it is unnecessary to search for indigenous, highly concentrated foods, such as acorns and leguminous seeds.

*Effect of Agriculture.* It is a generally accepted opinion that the prairie chicken increased greatly with the advent of agriculture, until the latter engulfed the greater portion of the prairie areas. It is difficult to find convincing support for this view. In autumn, during the hunting season, the birds left the prairie in large part and concentrated in the vicinity of corn and stubble fields. This influx could give a false impression.

Opinions varied greatly as to the extent of the increase. Kennicott[69] states merely that for a few years after the settlement of the Chicago area, prairie chickens increased rapidly. In 1847, a Chicago resident having fourteen years' acquaintance with the prairies, thought that they had more than doubled in that time.[70] At the same time and place another observer thought that the increase was eight-fold.[71] Thurston[72] came to Rockford, Illinois, in 1837, and mentions that during a period of five years the prairie chickens increased more than ten-fold due to a better food supply. If the observer arrived in a region at the bottom of a cycle, subsequent increase would be attributed to the most obvious factor, agriculture.

Writing in 1874, Bogardus[73] states that the pinnated grouse had learned to use the cornfields in late autumn and, that when he came first to Illinois (1857), they were to be found for the most part in the prairie grass. Subsequent writers have given this statement more importance than it deserves for the use of cultivated ground was old. Hall,[74] writing with special reference to the Illinois prairies, mentions that in autumn the grouse assemble round the cornfields and wheat-stacks in search of food. A gentleman[75] who settled in Kenosha County, in 1845, writes of the thousands of prairie chickens that collected in the fields of corn and buckwheat. In September, 1838, Captain Levinge[76] came to Chicago to hunt pinnated grouse. About ten miles west of Chicago, eight brace were shot, the birds being described accurately. His destination was the Fox River where grouse were stated to abound on account of the cultivation along its banks. Here game was found in great quantity.

It has been inferred from the statement of Bogardus that the prairie chicken had to learn to eat corn.[77] It is doubtful if this was the case in the sense that any appreciable time was required. Thomas,[47] writing in 1816, states that the prairie hen is fond of corn and grain. During a heavy snow storm in January, 1820, in what is now Gallatin County, Illinois, nearly all the grain in a field of standing corn was devoured by prairie chickens and other birds.[46a] In central Illinois, the prairie chickens ate so much of the corn standing in the fields as to be greatly injurious.[69] The Indians raised sufficient corn so that it could not have been a novelty. It was estimated that, in 1831, 1832, and 1833, they produced not less than three thousand bushels in the vicinity of Madison,[78] Wisconsin.

Corn as a food is conspicuous since it was usually the first crop raised by the settler, and because it could be left standing throughout the winter without being injured by the elements. Normally corn was planted on the freshly broken prairie and was called "sod corn". A hole was punched into the sod into which the corn was dropped. Though there was no cultivation, no grass and only a few weeds grew the first year.[79] A single plowing was sufficient to destroy the original prairie grasses and then weeds became an annual pest. The increased supply of weed seeds must have been a potent factor in drawing the birds to cultivated ground. Bogardus[73a] mentions that there was a great variety of foods obtainable in the cornfields, but that they preferred to feed in flax stubble and patches of navy beans rather than in cornfields. It has also been stated that the original prairie could not be mowed for hay for more than a few years before the weeds took possession.[80] Many farmers broke more prairie than they could cultivate subsequently so that hundreds of acres were covered with "a rampant growth of weeds."[81]

*Burning of the Prairies.* An agent most destructive to the prairie chicken was the prairie fire. It can be argued with plausibility that, for a period, agriculture contributed more to a peak population for this species by reduction of burning than by an increased food supply. However occasional burning was absolutely necessary for maintenance of the prairie; otherwise large areas would have reverted to forest and brush. The Indians fired the prairies from time immemorial. Fall fires not only destroyed food and winter cover but nesting cover as well for the following spring. Late spring fires destroyed the nests. Prevention and restriction of these fires were of prime importance to the first settlers.[82] Frequently there were heavy material losses in the shape of stacked hay and grain, fences, and even farm buildings.

The bleakness and lack of life on the burned prairie has been mentioned by many writers. Hoffman[15a] crossed a snow-free burned prairie in winter near Hennepin, Illinois. On reaching broken ground, where there was some shrubbery, a flock of grouse arose every moment. Due to the burning of the country for a great distance, Featherstonhaugh[27a] found the grouse congested along the banks of the Minnesota River where there were water and seeds of various kinds.

The burning of the prairie in late spring was considered by Kennicott[69] as highly injurious, due to destruction of the eggs. Some farmers recommended burning in the spring, after nesting had started, in order that there should be fewer young birds in the fall to eat the grain.[83] A few years later, the farmers were urged to seek some protection for the prairie chickens since they contributed greatly to the destruction of grasshoppers that were becoming very abundant on the Illinois prairies.[84]

Judd[85] was informed by E. W. Nelson that the farmers in northwestern Illinois, in the early seventies, burned the prairies in the spring after nesting had started and afterwards gathered large numbers of eggs for household use. The same situation existed in Iowa. Prairie chickens were scarce in Iowa in the fall of 1867. The reason given was that owing to the late, wet spring, the prairies were not burned until nesting had started.[86] A prairie fire in 1868 or 1869 ruined eggs by the thousands.[87] As late as 1896, Johnson[41] stated that "the habit of farmers to burn off the old grass from all the sloughs, ditches and swamps, about the time the first clutch is laid, has been, and is the means of destroying more birds than all the guns in the state." Prior to the settlement of northwestern Iowa, Newell[42] saw on the average four nests to the acre after a spring burning.

The frequency of fires can be judged from the remarks of Grinnell.[87a] In January 1845, he passed over a large prairie in Dodge County that had just been burned. Shortly afterwards he arrived at a marsh that the Indians were firing to drive out the game. While at Racine in April, the burning prairies were "lighting up the western sky." Skavlem[87b] has left a vivid picture of the effects of burning in late spring in Rock County. Often the virgin prairie was guarded from fire and not burned until prior to "breaking" in order to destroy the vegetation as completely as possible. The operation began the latter part of May and continued into July. The prairie birds, such as the prairie chicken, concentrated in the unbroken prairie to nest so that the burned area presented a dismal array of scorched eggs and the charred bodies of young birds. During the '50s when it was customary to shoot grouse as early as July there are frequent references to the small size of the young birds. On August 10, 1854 birds were offered for sale in Milwaukee "hardly as large, and certainly not as heavy as good quails."[88] It is reasonable to suppose that second nestings were due largely to burning of the prairies in April and May. Cold, wet springs were destructive to the young but if only one or two of a brood survived the female would not nest a second time.

*Hunting and Trapping.* Hunting with dog and gun began in late July.[89] The young prairie chickens, killed so easily at this season, were considered a delicacy. Many, however, thought that the bird was not good for the table until September, and that it was poor sportsmanship to shoot prior to that month.[90] On the approach of cool weather they were more difficult to secure as they gathered in large packs and were wary. Some asserted that even in early September it was difficult to secure more than two or three brace in a day; and that after the first frost they were scarcely obtainable with dog and gun.[91]

In late fall the prairie chickens were found on the trees early in the morning. Bunner[91] mentions that under these conditions it was impossible to secure them except by riding under the trees, or approaching behind oxen or horses. Then they could be killed in great numbers.

When snow covered the ground the prairie chicken took to the tops of trees and hedges.[92] Gerhard[61] has described the hunter's procedure: "Dressed entirely in white, with his face also painted white, save two great spots below the eyes, which are painted black to absorb the rays of the sun, he manages to advance stealthily within a short distance of the prairie fowls, sitting on the hedges [osage orange]." During a light snow storm, Bogardus[93] dropped nine birds from a fence at one discharge.

The number of birds killed by the gun was small in comparison with the many thousands taken by trapping. When snow covered the ground, they came into the barnyards to feed with the domestic fowls and were taken easily. The methods of trapping were numerous, but only two of the devices commonly used will be mentioned. "Atticus"[94] describes the trap used by the farmers near Racine in 1844. It consisted of a box open at the bottom, the top being covered with slats. The ends were provided with light wicker gates that swung at the top. They could be pushed up easily from the outside but not from the inside. Grain was scattered inside and at the entrances to induce the birds to enter. The tip-up trap is mentioned by Duis[95] as the "fall-door trap." A rectangular hole was dug in the ground and covered with a board pivoted near the middle. One end of the board rested on the ground while the other end was free. A bird attempting to reach the bait placed on the free end slid into the pit, the board dropping back into place.

*Primitive Abundance.* Owing to the migratory habit of the prairie chicken, it is desirable to consider first the status of the species in the region south of Wisconsin. Audubon,[35a] when he came to Kentucky in 1807, found pinnated grouse so abundant that no professional hunter would deign to shoot them. One winter's morning, a friend of his killed forty for the sake of rifle practice. By 1834, he thought that the species was decreasing at a rapid rate even in the state of Illinois. Thomas,[47] in 1816, believed the prairie hens to be more numerous in winter along the lower Wabash than quails were in the state of New York. Blane[36] remarked that a traveller on the prairies in the vicinity of Albion, Illinois, must be impressed by the "vast number" of grouse. The statement of Hall,[96] in 1838, is more impressive: "The number of these birds is astonishing. The plain is covered with them in every direction; and when they have been driven from the ground by a deep snow, I have seen thousands—or more properly tens of thousands—thickly clustered in the tops of the trees surrounding the prairie."

The prairie chicken was common also in regions practically untouched by agriculture. Hubbard[97] was in charge of an Indian trading post near modern Hennepin, Putnam County, Illinois, in the winter of 1818-19. Prairie chickens and quails, though "abundant," were considered a poor diet.

There is little to support the statement of Hatch[98] that, in Illinois in 1836, a good daily bag for an expert wing shot was ten or twelve birds, while later bags of fifty to sixty, or even one hundred were common. In general there was no shortage of grouse. In McClean County, in the winter of 1834-35, two boys trapped 750 prairie chickens as they came to feed on flax seeds.[95a] On the morning of January 16, 1834, in La Salle County, the oak trees were so covered with prairie chickens as to remind Hoffman of passenger pigeons.[15b] At Rockford, Illinois, in 1838, "the prairies were filled with pinnated grouse."[72a] In July, 1838, in crossing the prairies between Princeton and Dixon, Jones[79a] saw "innumerable prairie hens."

Some evidence of the abundance of grouse in early Wisconsin was given in the section on distribution. When Rodolf[99] came to Lafayette County in 1834, prairie chickens were abundant. Writing from Mineral Point, September 6, 1837, General Smith[100] mentioned that "the grouse or moorfowl are constantly flitting across the landscape." General Kellog[101] crossed Rock Prairie in September, 1840. His dog accustomed to hunting ruffed grouse was puzzled at the "immense flocks" of prairie chickens that were flushed. A year later, another traveller in southeastern Wisconsin had indifferent success. A day's travel through the fine prairies bordering the Fox River failed to produce the sight of a deer, prairie chicken, or prairie wolf. Between Janesville and Madison, several covies were flushed, while near Aztalan eight birds were secured.[102] However prairie chickens were by no means scarce that year. They were so plentiful in January, 1842, in the Milwaukee market that they were considered as only common fare.[103] Live and dead birds sold respectively at 31¼ and 25 cents a pair.

Skill at shooting on the wing was not possessed by many hunters during the first years of settlement, so that it is difficult to judge the population density from hunting data. During a side hunt that took place at Racine in 1836, a Frenchman, one Jambeau, is credited with having killed twenty prairie chickens in a forenoon.[104] A hunt that took place at Kenosha, in 1843, the number of hunters participating being unknown, resulted in the taking of "515 grouse."[105] At this time in the Racine region, it was not considered uncommon for an individual to shoot 20 or 30 birds in an afternoon.[106] In 1844, two men from Hazel Green, Grant County, spent a day on the prairie and shot one hundred "prairie hens."[87b] A good shot with a well trained dog could kill 50 to 75 birds in a day in the vicinity of Chicago,[107] so that the species seems to have been equally abundant in the two localities at that time.

The number of birds that a hunter killed in a day did not change materially for a period of ten years. Doctor Marsh[108] has recorded the results of several hunts on Howard's Prairie, near Milwaukee. On September 12, 1845, he shot "24 grouse," while on October 21, he and a companion secured but 10 due to the birds being in large flocks and wild. On August 2, 1846, four men killed 60 grouse stated to be two-thirds grown; on August 14, five men killed 65; and on September 15, he obtained 32 birds. In 1847, two men rode out of Milwaukee fifteen miles and returned the same day with 60 prairie chickens. Another party of five men drove twenty miles from Milwaukee and returned the same day with 124 birds.[109]

In 1848, individual daily bags on the Chicago prairies ran from 50 to 80 birds, with claims of 100 to 150 for other portions of the state.[110]

The potential bag for the Racine region in 1849 was 60 to 90 birds daily.[111] Hoy,[112] in 1852, said that two hunters with one dog generally secured 50 to 80 birds in a day at Racine. Elsewhere he states, that prior to 1858, a sportsman could shoot 40 to 60, or more.[113] Critical examination of the data given above shows that generalizations produced larger daily bags than did cases.

*The Decline.* It is impossible to make any definite statement as to a peak of abundance. There are insufficient data to prove that agriculture resulted in the great increases assumed by some writers. As mentioned previously, the pinnated grouse were widely scattered over the wild land during the breeding season and assembled near cultivated fields in autumn. It is easier to trace the decline, though obviously this did not occur at all uniformly in point of time throughout the bird's range.

The decline in northern Illinois began about 1850, on the authority of Thurston.[72b] He states: "The number of pinnated grouse from 1846 to '50, in Winnebago, Boone, and Stephenson counties was prodigious . . . I knew a company of nine, two only being expert shots, to go out in 1846, on Bonus Prairie, Boone County, who brought in over 300 chickens." These birds were shot in a distance of one and one-half miles, the men walking 25 feet apart. The party had but one dog and many more were assumed to have been killed and not found as the grass was knee-high. Thurston and a companion, on one occasion, shot 52 birds in a walk of two miles.

It is not far from correct to assume that the decline started about 1850. In December of that year, a professional hunter appeared in Chicago with 300 prairie chickens and 6 geese that he spent nine days in securing.[114] In 1851, judging from game receipts in Chicago, there was "about the usual crop of Grouse."[115] There was a noticeable drop in 1854. In the fall of that year, prairie chickens were selling at 20 to 25 cents apiece in the Chicago market, and were considered "scarce and high."[116]

In Wisconsin, prairie chickens were comparatively scarce in 1853, due supposedly to excessive trapping during the previous winter;[117] but the most noticeable decline came about 1855. The birds were fairly common in certain localities in 1854. In September of this year, three men hunted on Eagle Prairie, near Madison, "the farmers being widely scattered." One flock of 150 birds was seen, and 91 secured in a day's hunt.[118] In July, prairie chickens were reported as very plentiful about Madison. One hunter bagged 43 birds within "a few hours," while another shot 143 in a hunt of two days' duration.[120] Prairie chickens were abundant in the Milwaukee market where they sold for 10 cents apiece. On the other hand they were exceedingly scarce about Racine.[122]

Prairie chickens were plentiful, in 1855, in the vicinity of Watertown,[123] and in a few other localities. Schurz[44] wrote from Watertown, on August 12, that he and a companion hunted from early morning until nearly sunset, and that their bag contained only two prairie chickens. Had the hunt stopped at this point, the logical conclusion would have been that the birds were exceedingly scarce; but, "at the edge of a wet tract, we suddenly found ourselves in the midst of such a multitude of prairie chickens that we could hardly take time to load. In half an hour our hunting bags were full . . . "

At Madison,[124] two men shot 128 birds on August 25, while at Oakwood Grove,[125] Rock County, one man shot 20 prior to 8:00 A.M. These are unusual bags. Three boys at Mineral Point[126] shot 25 birds within a few hours. This was considered exceptional success in view of the scarcity of this game in the vicinity.

Prairie chickens were offered for sale in quantity at Watertown in 1856.[127] Nearly every farmer arriving in town in December brought with him "a dozen or more"; but this statement shows that the decline was well under way. Several hundred live birds were offered for sale in Madison, but this was considered "a sight even in our streets."

The year 1857 showed so sharp a drop that it may be considered the low of a cycle. The scarcity was attributed to the severity of the preceeding winters. At Jefferson, the birds were anything but plentiful.[129] They were scarce also at Janesville,[130] Madison,[131] Weyauwega,[132] and LaCrosse.[133] In January, 1858, prairie chickens were "unusually scarce" in the Milwaukee market.[134]

*Causes for the Decline.* It was recognized, as early at least as 1854, that cold wet springs, or heavy rains killed the young birds.[135] The destruction of eggs and young by the elements was considered as only a seasonal effect.[49]

At this time also it was believed that the severity of the winter was of little influence.[49] However, when the sharp drop of 1857 arrived, it was attributed to the severity of the past two winters, apparently for want of a better reason.[130] The severe winter of 1874-5 produced several reports of the decimation of the prairie chickens.[136] Pond[137] reported that the day following a temperature of 40° below zero, only one-half of a flock of pinnated grouse returned to their poplars to feed; however, when the shooting season opened, the birds were considered more plentiful than the year previous. There is little evidence that cold alone had a pronounced effect on the population.

The habit of the prairie chicken of roosting beneath the snow was sometimes fatal due to the formation of a crust through which they could not break. In 1881, pinnated grouse were found frozen in the sloughs and marshes at Rosendale, Wisconsin, after the February storms.[138] A crust that formed on the snow in the northwestern part of the state in January, 1888, is stated to have caused the death of great numbers of prairie chickens. They were found during the subsequent thaw.[139]

The decline of the prairie chicken began before there was any clear evidence for a cycle. The sole tenable cause for the decline is the construction of railways that permitted the rapid transportation of game to Chicago, and thence to the eastern markets. There was much trapping and shooting for the local markets but this was not of prime importance.

The Chicago market was supplied abundantly with grouse, selling at $1.25 per dozen, in 1845.[140] A market hunter, from April 1, 1847 to April 1, 1848, killed and sold in Illinois 2420 prairie chickens.[141] Grouse, about three-fourths grown, were plentiful in July, 1848, at 75 cents a dozen.[142] During the latter part of January, 1850, 5000 prairie chickens were forwarded by express to New York City, and the trade was increasing rapidly.[143] A year later "thousands" of prairie chickens were being shipped from the Chicago region, there being specific mention of one shipment of 6000 birds from Michigan City, Indiana. Lake

County, Indiana, during a period of six weeks sent 20,000 prairie chickens to Detroit.[144] By 1853, the shipments of quails and prairie chickens had reached such proportions that they were designated by the "cord" and the ton.[145]

A shipment of prairie chickens from Wisconsin was received in Washington in February, 1846, where they were sold at one dollar per pair. The species was considered a *"rara avis"* in those parts.[146] Shipments were light, however, prior to construction of the railroads. A line from Chicago reached Beloit in 1853 and Madison in 1864. Another from Chicago to Milwaukee was completed in 1855. The Milwaukee and Mississippi River Railway, begun at Milwaukee in 1849, was extended to the Rock River Valley in 1853 and to Madison in 1854. By 1857, 1858, and 1859, Prairie du Chien, La Crosse, and Fond du Lac, respectively were connected by rail with Milwaukee. The best regions in the state for prairie chickens had been invaded.

The killing of game had reached such heights by 1851 that Wisconsin passed its first game law. This included the protection of prairie chickens from February 1 to August 1. A year later the law was amended to read from January 1, the reason being that in January, 1852, large numbers of prairie chickens had been caught and shipped to New York.[147] The shipments of game birds were so immense that fears were expressed of the possible extinction of certain species.[148] On February 12, 1852, the city of Milwaukee supported the state law by passing an ordinance prohibiting the sale of "pinnated grouse (known as the prairie hen, or prairie chicken)" between February 1 and the first Tuesday in August.

Shipping facilities by rail and water turned hundreds of farmers and their sons into diligent hunters and trappers. As an example of individual activity, Joseph Clason of Beaver Dam brought to Milwaukee on February 1, 1853, 100 dozen quails, 200 prairie hens and 100 partridges, that had been shot and snared by his son.[149] There were heavy shipments of gamebirds, including prairie chickens, from Watertown during the winter of 1854-55.[150] Though extinction was feared for the prairie chicken as a result of the trade,[151] little attention seems to have been paid to the law. The birds were marketed in Watertown[152] and many other places in the spring. Subsequently there was some attempt to enforce the law for in April, 1859, two Norwegians were fined five dollars each and costs for offering live prairie chickens for sale in Madison.[153]

In the winter of 1855-56, "tuns of Quails, Patridges and Grouse" were to be seen hanging in the yard of the Capital House at Madison. Stores had large quantities of these birds for sale throughout January and February.[154] The comparative scarcity of game at Janesville, in 1860, was believed due to the exportation several years previously, of tons of prairie chickens and quails.[155] Scarcity at Madison was attributed to the fact that "since railroads reached us, the prairie chickens have all taken passage east."[156]

*Cycles.* It is probable that cycles are prehistoric, but, in the absence of statistical data, it is impossible to determine if they existed at the beginning of settlement. There are consecutive annual references to the abundance of prairie chickens from 1831 to 1855. The probable reason for this is that "abundance" is an elastic term, the connotation varying with the user. Cycles might have shown less extremes than later, or a regional shortage might have been obscured by immigration.

A note from Racine dated July 18, 1849, states: "The Grouse are always abundant. In August, or the early part of September, you can make a great bag in a day, say from sixty to ninety . . . "[111] Nevertheless conditions varied. At Potosi, Grant County, in 1852, grouse were reported to be more numerous than they had been for the past six years.[157] There was the scarcity of birds in the Milwaukee market in 1853, mentioned previously. The following year Bunner[158] wrote from Janesville: "It is said that the birds are not so plenty as they were, and are decreasing annually. This we doubt very much. They are not to be got at so easily, being wilder and more cunning, taking more to cornfields, where they are perfectly safe, rising earlier than they used to, flying to much greater distances, and taking better care of themselves. You cannot shoot as many as you could once, for these reasons." The scarcity for 1854 was attributed to the heavy rains that killed the young. His statement that when a man can shoot a dozen birds in an afternoon, "it is abundance," is enlightening. A few years earlier this would have been considered an indifferent bag.

In 1856, another writer,[159] mentioned the prairie chicken as a bird that was "certain as well as abundant." The following year there was the first sharp low. That the prairie chicken reached its peak about 1855 is shown by the following: "An experienced hunter arrived in town (Madison) last evening with upwards of 30 prairie chickens, all shot within ten miles of here. Very good work for a two days' hunt. But fifteen years ago [1855] Andrew Bishop would go west about twelve miles, and bring down 75 of the precious creatures in about four or five hours' shooting."

The annual status of the grouse in Wisconsin from 1855 to 1897 is shown in the appendix to this paper. Examination of the data reveals well-defined lows in the years 1857, 1867, 1878, 1887, and 1897. The length of the cycles* varies from 9 to 11 years. The agreement with Criddle's[160] data is unexpectedly good. He found a 9 to 11 year cycle for the sharp-tailed grouse in Manitoba, the lows falling in the years 1897, 1907, 1918, and 1927. This confirms the assumption that the cycle for the two species of grouse is identical. The 1897 coincidence of the lows for Manitoba and Wisconsin must for the present be considered fortuitous. There is no reason to suppose that the lows will be identical chronologically throughout the ranges of the prairie chicken and sharp-tailed grouse.

There is no suggestion in the early literature that disease caused fluctuations in the number of grouse. Writing of the prairie chicken in Illinois, in 1889, Dr. F. H. Yorke[161] called attention to the "grouse disease" that appears when the pastures are alive with this game. That same year a sportsman at Menomonie, Wisconsin, seems to have recognized the progress of a cycle, for he wrote: "Birds [prairie chickens] are scarcer this year than last; they were less plenty last year than the year before, and next year they will be fewer than they are now."[162]

A hunter at Plover, Wisconsin, in the autumn of 1886, called attention to what to him was a remarkable phenomenon.[163] There was an unusual number of wood ticks on the necks of the prairie chickens that he shot, as many as thirty being found on one bird. The grouse cycle reached a low the following year, but several decades passed before any relationship between the tick and disease was recognized.

* Only the average annual population of the state are of value in determining cycles.

*The Future.* Predictions in many cases prove futile, but the future of the prairie chicken cannot be viewed with optimism. During a residence of 33 years in southern Wisconsin, I have seen this species dwindle until it has become relatively rare. Much valuable research has been conducted during the past 15 years, but the answer to the problem is not in sight.

While agriculture may have increased the population for a brief period, the damage resulting from the destruction of its natural habitat by the same agency can scarcely be repaired. The prairies of the uplands are extinct, and there are few in the lowlands that have not undergone profound change. The result has been to force the species northward into localities that to the best of our knowledge were not occupied in primitive times. The prairie chicken reached Lake Superior due to the felling of the forests and the opening of farms.

Many of the marshes of the Central Plain were drained in the vain hope of obtaining a permanent agriculture. The drained lands, including the abandoned farms, are reverting to brush. There is little hope of recovering even this territory by judicious burning.

A factor that cannot be overlooked is the fact that our prairie chickens are virtually isolated. In primitive times vast flocks moved southward in autumn and returned in spring. It was possible in this way to obtain recruits from other regions. The fall movement through Wisconsin into Illinois, or even into southern Wisconsin, has long ceased. If the migrating flocks consisted largely of females, as is supposed, there must have been a good physiological reason. Localization of the present small population may render the species incapable of surmounting crises. It is clear from the early records that the lows of the cycles were not as severe, nor the recoveries as delayed, as they are at the present time. Whether this is due to cessation of distant migrations or to a more obscure cause remains to be determined.

## PART II. THE SHARP-TAILED GROUSE

The original southern range of the prairie sharp-tailed grouse (*Pediocetes phasianellus campestris*) in the Mississippi Valley is known imperfectly. Coues[2] draws the inference that it once occupied all the suitable prairie land of Iowa, Wisconsin, and Michigan. Tanner,[164] writing from Burlington, Iowa, in 1837, evidently had this species in mind, when in discussing the prairie chicken he mentions that its habits differ "in some respects from the northern bird of the same kind . . . "

Formerly, it was not uncommon in Cook County, Illinois,[69] but there is no authentic information that it ever occurred south of the latitude of Chicago. Nelson,[165] writing in 1876, stated that it was then confined to the northwestern portion of the state. The species persisted near Waukegan until 1863 or 1864, when a covey of fourteen birds was secured. Brewer[166] mentions seeing a flock within thirty miles of Chicago but gives no date. The prairie chicken probably outnumbered greatly the sharp-tailed grouse in northern Illinois. Thomas Say, naturalist to Long's Second Expedition, in 1823, mentions that the birds seen between the Des Plaines and the Fox Rivers were *Tetrao cupido*.[167]

*Range in Wisconsin.* The sharp-tailed grouse was to be found actually or potentially in all parts of the state. It has a preference for brushy and park-like areas, and in the prairie regions of southern Wisconsin occurred most commonly in the oak openings. From this habitat it acquired the vernacular name "bur oak grouse." Usually the sharp-tailed grouse was not distinguished from the prairie chicken due to similarity in appearance and habits. There is no question, however, but that at the beginning of the nineteenth century both species occurred in the southern portion of the state. The opinion has prevailed that the sharp-tailed grouse was the dominant if not the sole species up to the beginning of agricultural development, *i.e.*, about 1840. The belief is erroneous and is based on meager data.

It was formerly common near Racine but had become rare by 1852.[112] Charles Rodolf[168] settled at Wiota, Lafayette County, in 1834. He mentions that "grouse, prairie chickens, pheasants [ruffed grouse]" were plentiful. Valentine,[169] on the authority of old residents, states that it was found formerly in all the southern Wisconsin counties. An annonymous writer mentions that while traveling in southern Wisconsin, in the winter of 1842, he saw "many of the burr oak grouse, as they are called by the inhabitants, sitting on trees by the road side."[170] They were observed again the following summer in the region between Milwaukee and Madison: "Their habits resembled those of the pinnated grouse, excepting that they inhabited by choice, the groves instead of the prairies." Another writer mentions it as abundant in 1840-45 in southern Wisconsin and northern Illinois, as far south as Chicago, "always frequenting the timber. . . ."[171]

The sharp-tailed grouse, according to Kumlien and Hollister[5] was the common species of grouse on the prairies of southern Wisconsin in 1840 and at that time was extremely abundant. Thure Kumlien, who came to Lake Koshkonong in 1843, resided there several years before he saw the common prairie chicken. It is probable that at this period there were comparatively rapid changes in vegetation and hence in the resident species of grouse. Attention has been called elsewhere to the fact that when burning of the prairie ceased, the surface was covered quickly with a growth of trees.[172] The change that could take place is shown significantly by the following description of an area at Oregon, Wisconsin: "The cover here is getting to be abominable, a perfect tangle of scrub-oak, chokecherry, wild crab-apple, hazel-brush, frost-grape and a variety of briars, with now and then a little patch of tolerably clear poplar for relief."[173] A prairie inhabited by the prairie chicken could be covered with brush in a few years, and then be taken over by the sharp-tailed grouse; hence, species dominance is of no significance except for the limited area and the particular time under discussion. The two species were respectors of habitat and there is little overlapping in breeding areas even today.

The best statement on the early status of this species was written in 1856 by a Milwaukee sportsman: "Of the grouse of our prairies, two kinds exist in Wisconsin, or did until very lately, the one known to all of our readers, the other very much like it, but with two long tail feathers at the sides of the fan . . . It was once quite abundant within thirty miles of the city, about as much so as the ordinary grouse, but it does not seem to like the presence of mankind so well, and has moved to more distant regions . . ."[174]

In connection with relative abundance and distribution, there is the following remarkable statement from New Libson, in 1859:

"Mr. L. showed us a fine lot of grouse . . . and until informed by him of the fact, we were ignorant of the presence of this bird in this section. They are a heavier and much prettier bird than the chicken."[175] It is unexpected to find the prairie chicken the predominating species at New Libson at this time.

The early writers were in general accord in believing that the sharp-tailed grouse was a heavier and more handsome bird than the prairie chicken, and of superior flavor. Van Dyke[176] hunted sharp-tailed grouse in the eastern portion of Buffalo County, Wisconsin, in 1870. He mentions shooting a bird, weighing nearly four pounds, that was in every respect a more handsome and imposing bird than the prairie chicken. From a circular area less than 200 feet in diameter, his party secured 27 fully grown birds weighing almost 100 pounds. These weights are far beyond the average. Smith,[177] hunting near Augusta, found that 8 birds weighed exactly 15 pounds, or slightly less than two pounds per bird. This weight checks quite well with the findings of Gross.[178] He gives the average weights of males and females as 1.82 and 1.58 pounds respectively.

*Migration.* The sharp-tailed grouse has been considered to be more or less migratory in autumn. There were periodic movements of considerable extent in former times but little is known about them. The only detailed study is that made by Snyder[179] on the migration in Ontario in the winter of 1932-33.

It is stated that in the severe and snowy winter of 1844, this species came farther south than usual and several fine specimens were secured in Chicago.[180] Two or three winters later, some were also killed in the vicinity of Chicago. These birds could have been of local origin or migrants from southern Wisconsin. There is no evidence of a wide-spread movement.

In determining the movements in Wisconsin, it is extremely difficult to determine to which species the statements refer. The appearance of "prairie hens" in the vicinity of Chicago during subzero weather in January, 1852, was, in the popular belief, an indication of a hard winter.[181] February proved to be very mild with insufficient snow for good sleighing. The statement from Green Bay, in November, 1854, is equally indefinite: "Coming North. We hear of many flocks of Grouse in the vicinity recently. Though they have been seen here, at intervals, they are nevertheless rare."[182] It is a mere inference that the birds came from the south. Leopold,[183] quotes Orrin Sutherland, born at Janesville, Wisconsin, in 1849, as saying that in the '50s: ". . . great flights of grouse (sharptails) arrived late in fall when snow came, in flocks of 100 to 150, flying about 15 rods high. . . . In the spring they went back but not in continuous flights; they just strung back." The description of the fall and spring flights is typical of the prairie chicken. Considering Sutherland's youthfulness at the time, and that both species were commonly called "grouse," there is doubt that the flights consisted of sharp-tailed grouse.

The first clearly defined movement took place at the head of Lake Superior in November, 1865. This region was safely beyond the range of the prairie chicken at that time. Concerning this movement it is said: "Grouse or Prairie Chicken, which for the past two years have been occasionally seen in this locality, are this fall to be found in great numbers around the head of the lake. They have been shot in the heart of the town during the past week. A gentleman who came up the north shore lately informs us that on every promontory or point along the coast, they were to be seen feeding like so many domestic chickens."[184] During the following week the citizens of Superior had excellent shooting up to 10:00 A.M. every morning. The number of birds involved must have been great for a Mr. Curtice who had been surveying in Minnesota reported them "as very plentiful as far as fifty miles north of the lake."

The extent of this migration is unknown. Snyder[179] mentions that a sharp-tailed grouse taken at Sault Ste. Marie was exhibited at a meeting of the Canadian Institute held in Toronto on January 13, 1866. He assumes that the bird was the northern form, *P. p. phasianellus*, and that hypothetically there must have been a considerable movement during the winter of 1865-66. The actuality of the flight has been confirmed, and it is within the realm of possibility that the Minnesota flight consisted of *phasianellus* rather than *campestris*. Against this assumption is the fact that *phasianellus* has never been taken in Minnesota; also, since there was a congestion on the shore of Lake Superior it seems that the movement originated in the west or northwest.

The first mention of a "prairie chicken" in the vicinity of

Superior was in November, 1864, when several were killed. They were stated to have come from the open country of the St. Croix River.[185] This was followed by the large migration of sharp-tailed grouse in the fall of 1865. Nine years later, September, 1874, "prairie chickens" were seen again.[186] In August, 1883, a hunter is stated to have bagged fifteen.[187] The data are too few to determine if the nine-year intervals are of significance.

In the winter of 1867-68, there was a considerable flight of sharp-tailed grouse from Wisconsin to Lake City, Waubesha County, Minnesota. Gibbs[188] says: "One snowy morning last winter a flock of them came across Lake Pepin, and stopped to rest in the trees, and on the houses and barns all over Lake City. For a few minutes you could hardly look in any direction about town without seeing them standing like statues in all directions, their necks and heads pointed upward in a straight line, and seeming astonished at their situation and afraid to stir a feather. They are often seen in the trees in the villages, but rarely in large numbers." It is probable that this represented only an unusually large local movement.

*Decline.* The sharp-tailed grouse, as a local bird, had become rare in southeastern Wisconsin by 1852,[112] and its existence in the region was in doubt by 1856.[113,174] For this reason it seldom reached the eastern markets, as its decline preceded the construction of the railways. DeVoe[189] says that this "fine bird" was found sometimes among the large number of prairie chickens shipped from Illinois, Iowa, and Wisconsin.

The last specimen for Rock County was obtained in 1869.[5] Thure Kumlien could still furnish specimens from Lake Koshkonong in 1862.[190] In 1865, it was still a common breeder in Dane County.[191] The species persisted in the county until recently. Professor J. G. Dickson has informed me that a small flock existed for several years near his cottage at Blue Mounds. They were seen last during the winter of 1939-40.

On July 11, 1934, I was told by Mr. William Dunwoody of Monroe, that he had heard that sharp-tailed grouse were still to be found in Green County, northeast of Argyle. It was to be found in the southern portion of Iowa County until 1900.[183a]

In 1883, some hunters at Reedsburg, Sauk County, had "two or three speckled prairie chickens. We never saw any prairie chickens marked just that way before. . . ."[192] Apparently these were sharp-tailed grouse.

At Oshkosh,[193] in 1851, "grouse and prairie chickens" were very abundant. The report of King[194] was completed essentially in 1878. He mentions that the sharp-tailed grouse was resident from Berlin northward, and that in October, 1877, it was abundant in the vicinity of Lac du Flambeau.

Hunters, in 1863, were bringing large numbers of prairie chickens into La Crosse,[195] where also "grouse, quail, partridge" were to be found. In Pierce County, in 1856, "pheasants, grouse and chickens" were plentiful.[196]

In 1870, the section of the state northwest of Sparta, Tomah, and Necedah contained more sharp-tailed grouse than prairie chickens[197] and it is doubtful if this condition was ever reversed. Both "prairie chickens and grouse" were plentiful near Chippewa Falls[198] in 1873. In September of this year, Smith[177] drove three or four miles from Augusta, where it was stated that both species would be found. The first afternoon he and a companion, hunting in the scrub," killed 18 sharp-tailed grouse and 3 prairie chickens. The following afternoon they saw a pack of not less than 300 birds. Both species were found in the stubble but even here the sharp-tailed grouse was more numerous. At this time the birds were in large packs and wild.

In the fall of 1881 both species were scarce in the Milwaukee market.[199] The two species were "very abundant" at Necedah in March, 1883.[200] They were listed as permanent residents at New Richmond, St. Croix County, in 1886: " . . . the partridge or ruffed grouse, common grouse, prairie chicken . . . may be found with us all the year round . . . " Early in February of this year "prairie chickens" were flying over the town nearly every morning.[201] It is uncertain to which species the flights refer.

The sharp-tailed grouse is not mentioned by Willard[202] in his list of birds of the Green Bay region, prepared in 1883, nor was it observed at this time by Grundtvig[203] in Outagamie County. On the other hand, it was a common resident of Oconto County in 1902.[204]

Hampton[205] hunted the sharp-tailed grouse at Babcock, in 1896, and did not find them very plentiful. He heard that there were some "pinnated grouse" in the neighborhood but he saw none. In 1897, all the birds killed at Hancock on the opening day were sharp-tailed grouse.[206] At this time Hough[207] wrote: "Wherever the wheat country runs up into the joining line of the hardwood and pine country there are some prairie chickens and very often sharp-tailed grouse in Wisconsin."[208] He hunted at Necedah in 1901 where he considered the two species about equally divided in number, or perhaps one-third was represented by the sharp-tailed grouse. It seemed odd to him to flush prairie chickens in an open field and have them fly straight into the pine timber. At Babcock, this season, he found that the sharp-tailed grouse predominated.

*The Future.* The anticipated extinction of the sharp-tailed grouse has not been realized nor is it within the realm of probability. There is every reason to believe that under present land policies the species will continue to be plentiful. The replacement of the virgin coniferous forests with hardwoods, the growth of brush on drained marshes, and the withdrawal of marginal lands from cultivation have improved its habitat in many sections of the state. It is thoroughly capable of thriving in regions untouched by agriculture. In fact, it seems to be incapable of existing without a certain amount of wild land.

## "Prairie Chicken" Annals

### 1855

The prospects for the state as a whole were considered excellent.[1] Prairie chickens were scarce at Mineral Point,[2] "quite plenty" at Hudson,[3] and plentiful at Madison[4] and Watertown.[5] One writer states that they were as plentiful during the winter of 1855-6 as they had been during any one of the past ten years.[6] During this winter they were plentiful in the markets at Madison,[7] Milwaukee,[8] Lancaster,[9] and Watertown.[10]

[1] Milwaukee (d) *Wisconsin* Sept. 1. [2] Mineral Point *Tribune* Aug. 14. [3] Hudson *North Star* Aug. 22. [4] Madison *Patriot* Aug. 28. [5] Watertown *Democrat* Aug. 30, [6] Milwaukee *News* Aug. 17, 1856. [7] Milwaukee *News* June 10, 1856. [8] Milwaukee *Sentinel* Jan. 25, 1856. [9] Lancaster *Herald*. In Milwaukee *Sentinel* Jan. 10, 1856. [10] Watertown *Democrat* Jan. 31, 1856.

### 1856

Large shipments were made from Watertown[1] and the birds were reported plentiful at Prescott[2] and Plover.[3] Several hundred live prairie chickens were brought to Madison[4] for sale. The few references for the year indicate that they were neither sufficiently numerous nor scarce to excite comment.

[1] Watertown *Democrat* May 1, Nov. 13, and Dec. 25. [2] Prescott *Transcript* April 12 and Aug. 15. [3] Plover *Herald* Sept. 11. [4] Madison *Patriot* Dec. 25.

### 1857

This year was a decisive low. They were reported scarce at Jefferson,[1] Janesville,[2] La Crosse,[3] and Weyauwega.[4] Several sportsmen at Watertown[5] returned "with bags well filled with snipe and prairie chicken." A few birds were offered in the Madison[6] market while in January, 1858, they were "unusually scarce" in the Milwaukee[7] market.

[1] *Porter's Spirit of the Times*, N. S. 3 (Nov. 28, 1857) 202. [2] Janesville *Gazette* Aug. 10. [3] La Crosse *National Democrat* Oct. 13. [4] Weyauwega *Weyauwegan* Nov. 15. [5] Watertown *Democrat* Aug. 13. [6] Madison *Argus* and *Democrat* Aug. 18. [7] Milwaukee *Sentinel* Jan. 4, 1858.

### 1858

In February, thousands of prairie chickens were reported to be using the cornfields in the vicinity of Wheaton and Danby, Du Page County, Illinois.[1] In Wisconsin, except at Jefferson,[2] they were more numerous than in 1857. They were quite plentiful at Waukesha,[3] Horicon,[4] Fox Lake,[5] Portage,[6] Madison,[7] and Prairie du Chien.[8] They were not sufficiently plentiful at Prairie du Chien, however, to prevent the local hunters from going to Iowa.[9] Milwaukee was "tolerably well supplied" with this game.[10] In December they sold at 14 to 15 cents apiece, the price dropping later to 10 to 12 cents due to poor weather for preserving game.

[1] Chicago *Tribune*. In Milwaukee (d) *Wisconsin* Feb. 13. [2] Milwaukee *Wisconsin* Aug. 14. [3] Waukesha *Democrat* Sept. 7. [4] Horicon *Argus* Sept. 3. [5] Fox Lake *Gazette* Aug. 3 and Sept. 7. [6] Portage *Badger State* Aug. 27. [7] Madison *State Journal* Aug. 16. [8] Prairie du Chien *Courier* Sept. 2. [9] Prairie du Chien *Leader* Aug. 28. [10] Milwaukee *Sentinel* Dec. 3 and 31.

### 1859

The birds were plentiful generally throughout the state. At Mineral Point[1] they were considered unusually numerous, and plentiful to abundant at Platteville,[2] Mauston,[3] Prescott,[4] Hudson,[5] Oshkosh,[6] Wautoma,[7] and Burlington.[8] A side hunt at Monroe[9] produced 211 birds. A party of eight men at Madison[10] shot over 150 prairie chickens in two days. A hunter at Janesville[11] killed 54 birds in one day, and three young men hunting at Lake Geneva bagged 83 in one day.[12]

[1] Mineral Point *Intelligencer* Aug. 4; *Tribune* Aug. 2. [2] Platteville *Witness* Aug. 4. [3] Mauston *Star* Sept. 21. [4] Prescott *Democrat* Aug. 27; *Transcript* Aug. 27 and Oct. 8. [5] Hudson *North Star* Aug. 17. [6] Oshkosh *Courier* Aug. 12 and 15. [7] Wautoma *Argus* Aug. 5. [8] Burlington *Gazette* Aug. 30. [9] Monroe *Sentinel* Aug. 17. [10] Madison *State Journal* Aug. 17; *cf.* Janesville *Gazette* Aug. 22. [11] Janesville. Burlington *Gazette* Aug. 30. [12] Kenosha *Telegraph* Aug. 25.

### 1860

Prairie chickens were considered more abundant this year than the year previous due to the mildness of the winter and the heavy crops of grain.[1] They were reported abundant at Oxford,[2] Horicon,[3] Baraboo,[4] Burlington,[5] Shullsburg,[6] and Prairie du Chien.[7] Early in the season they were moderately plentiful at Madison.[8] The price of 12 to 15 cents on August 13 rose to 18 cents by September 7, when there was a general complaint of scarcity.[9]

The prairies of Eau Claire County were "alive" with the birds though they were smaller than usual.[10] A party of three men hunted at Bridge Creek killing 106 birds, the first day, and during a part of the following day added about 50 more.[11] Six men shooting in the southern part of Dane County killed 253 birds in two days, or 21.1 birds per gun per day. These men were experienced hunters and the reason given for the modest bag was that the covies were small, containing at the most only seven or eight birds.[12] They were plentiful in the Milwaukee market and sold at 15 to 18 cents.[13]

[1] Milwaukee (d) *Wisconsin* July 30; Madison State *Journal* Aug. 14. [2] Oxford *Express* Aug. 17

and 31. [3] Horicon *Argus* Sept. 21. [4] Baraboo *Republic* Aug. 15. [5] Burlington *Gazette* Aug. 14. [6] Shullsburg *Local* Aug. 10. [7] Prairie du Chien *Courier*. In Milwaukee *Sentinel* Aug. 4. [8] Madison *State Journal* Aug. 14; *Patriot* Aug. 13, 14, 24, 29 and Sept 7. [9] Madison *Argus* and *Democrat* Sept. 8 and Oct. 12. [10] Eau Claire *Free Press* July 19. [11] *Ibid.* Aug. 31. [12] Madison *Patriot* Aug. 15. [13] Milwaukee *Wisconsin* Aug. 4 and 14.

### 1861

Prairie chickens continued to be plentiful. One writer stated that the shooting at Prairie du Chien was the best in his remembrance.[1] They were abundant at Hudson,[2] La Crosse,[3] Galesville,[4] Mauston,[5] Markesan,[6] Oshkosh,[7] Fond du Lac,[8] and Watertown.[9] Oconomowoc[10] hunters had "unbounded success" near Waupun, but that of Madison[11] hunters was only moderate.

It is of special interest that the shooting was good this season along Lake Michigan. Good bags were made at Waukesha[12] and Kenosha.[13] At Racine,[14] two hunters shot 88 birds within a period of eight hours.

Milwaukee was supplied abundantly with birds at $2.00 a dozen.[15]

[1] Prairie du Chien *Courier*. In Milwaukee *Wisconsin* Sept. 11. [2] Hudson. In Platteville *Witness* Sept. 12. [3] La Crosse (t-w) *Democrat* Aug. 14 and Oct. 11. [4] Galesville *Transcript* Aug. 23. [5] Mauston *Star* Aug. 14. [6] Markesan *Journal* Sept. 7. [7] Oshkosh *Courier* Aug. 16. [8] Fond du Lac *Reporter* Aug. 10. [9] Watertown *Democrat* Aug. 1. [10] Oconomowoc *Free Press* Oct. 4. [11] Madison *Patriot* Aug. 17; *Argus* and *Democrat* Aug. 17. [12] Waukesha *Democrat* Aug. 20. [13] Kenosha *Telegraph* Aug. 15. [14] Racine *Advocate* Aug. 21. [15] Milwaukee *Sentinel* Aug. 20; *Wisconsin* Aug. 16 and 28.

### 1862

The Civil War eclipsed interest in hunting. The few reports available show that prairie chickens were plentiful. "Snap Shot,"[1] writing from Oregon, mentions that pinnated grouse "swarm" on the stubble-fields and dry marshes. They were numerous at Sparta[2] and Berlin.[3] At Kenosha,[4] three men shot 82 birds in a day's hunt.

[1] "Snap Shot." *Wilkes' Spirit of the Times*, N. S. 7 (Sept. 27, 1862) 55. [2] Sparta *Herald* Aug. 20. [3] Berlin *Courant* Aug. 28. [4] Kenosha *Times* Aug. 21.

### 1863

Prairie chickens were said to have never been "so abundant" in the Chicago market as during this season.[1] In Iowa, their numbers exceeded any known previously.[2] In January, 1864, a dealer at Fort Atkinson, Iowa, made one shipment of 360 dozen to New York.[3] The Dubuque market became so glutted with birds that they could not be sold at a sufficient price to pay the freight.[4] Conditions in Wisconsin were also favorable. The birds were abundant at La Crosse,[5] Galesville,[6] Baraboo,[7] Appleton,[8] Ripon,[9] Beaver Dam,[10] and Watertown.[11] At Beloit[12] two men shot 51 birds in four hours.

[1] *Wilkes' Spirit of the Times*, N. S. 8 (Aug. 29, 1863) 410. [2] Milwaukee *Wisconsin* Aug. 7 and Dec. 29. [3] *Ibid.* Jan. 22, 1864. [4] *Ibid.* Jan. 30. [5] La Crosse *Democrat* Aug. 11, Sept. 11, Oct. 10. [6] Galesville *Transcript* Aug. 21. [7] Baraboo *Republic* Aug. 19. [8] Appleton *Crescent* Sept. 5. [9] Ripon *Record* Aug. 13. [10] Beaver Dam *Argus* Sept. 9. [11] Watertown *Democrat* Aug. 27. [12] Beloit *Journal* and *Courier* Aug. 27.

## 1864

Prairie chickens were abundant due, it was believed, to the dryness of the season and so many hunters being in the army.[1] Nevertheless, owing to the drought, they were difficult to secure in the swamps and marshes, to which they retired.[2] They were plentiful at Osceola,[3] La Crosse,[4] Ripon,[5] and Fox Lake.[6] At Madison[7] they were exceptionally numerous. A full brood in Dane County ran from 15 to 20 birds.[8] South of La Crosse,[9] in December, the "innumerable" prairie chickens were a pest to the farmers owing to their visits to the barnyards and wheat stacks.

They were not plentiful at Beaver Dam,[10] and Paulson,[11] who hunted at Whitewater in August, found them scarce. A party of five men secured a modest bag of 60 birds in a day's hunt at Burlington.[12]

[1] Milwaukee *Wisconsin* Sept. 6. [2] Milwaukee *News* Aug. 23. [3] Osceola *Press*. In Milwaukee *Wisconsin* Aug. 5. [4] La Crosse *Democrat* Oct. 10. [5] Ripon *Commonwealth* July 29. Fox Lake *Gazette* Aug. 17. [7] Madison *State Journal* Aug. 6; *Patriot* July 26 and Aug. 29. [8] *Wilkes' Spirit of the Times* 11 (Sept. 17, 1864) 35. [9] Eau Claire *Free Press* Dec. 15. [10] Beaver Dam *Argus* Aug. 17. [11] Paulson, *Wilkes' Spirit of the Times* 12 (July 29, 1865) 339. [12] Burlington *Standard* Aug. 16.

## 1865

The birds continued abundant in many localities. In April the marshes at Portage[1] were alive with them. "Snap Shot,"[2] writing from Madison in May, predicted the best shooting in years. A side hunt at Eau Claire [3] resulted in 786 birds for one team of 25 men, and 452 for the other team of 20 men. This is a total of 1238 birds, and an average of 27.5 per gun. They were reported abundant at Osceola,[4] Hudson,[5] Ripon,[6] Green Lake,[7] Waupun[8] and Watertown;[9] and plentiful at Mineral Point,[10] Monroe,[11] and Madison.[12] One hunter, who with two companions killed 60 birds in a forenoon at Brooklyn, stated that he never saw them more numerous in the west.[13] Green Bay[14] had the best shooting in years.

The year 1864 appears to have been a peak year in Iowa as noted above. In 1865, 38 men participating in a side hunt in Delaware County, Iowa, killed 857 birds during the day. They were scarce in comparison with the year previous.[15]

[1] Portage *Register* April 1. [2] "Snap Shot." *Wilkes' Spirit of the Times* 12 (May 27, 1865) 194. [3] Eau Claire *Free Press* Aug. 17. [4] Osceola *Press* Aug. 19. [5] Hudson *Star*. In Madison *State Journal* Sept. 5. [6] Ripon *Commonwealth* Aug. 25. [7] Green Lake *Spectator*. In Madison *Capitol* Aug. 24. [8] Waupun *Times*. In Madison *State Journal* Aug. 19. [9] Watertown *Democrat* Aug. 17. [10] Mineral Point *Tribune* July 26. [11] Monroe *Sentinel* Aug. 23. [12] Madison *State Journal* Aug. 15. [13] J. P. S. *Turf, Field and Farm* 1 (Sept. 30, 1865) 138. [14] Green Bay *Advocate* Sept. 7. [15] *Turf, Field and Farm* 1 (Sept. 9, 1865) 92.

## 1866

The reports were few and somewhat conflicting. Prairie chickens were stated to be plentiful at Alma,[1] Osceola,[2] Prescott,[3] Hudson,[4] Neenah,[5] Ripon,[6] and Madison.[7] W. S. Grubb,[8] of Madison, shot 52 birds in one day near Sauk City. Two men hunted near Middleton Junction, Dane County, and killed 65 "grouse" in two days.[9] A party of six men is credited with shooting 300 birds in one day at Black River Falls, but later they were stated to be less numerous in the same locality than for some years.[10] A report from Fond du Lac[11] reads: "Prairie chickens are not as plenty this season as they were a year ago, owing no doubt to the wet weather in the earlier part of the summer." The Milwaukee market received large quantities of birds during the middle of August.[12]

[1] Alma *Journal*. In Milwaukee *Sentinel* Oct. 17. [2] Osceola *Press* Sept. 22. [3] Prescott *Journal* Aug. 18. [4] Hudson *Star* and *Times* Aug. 21. [5] Neenah *Island City Times* Aug. 21. [6] Ripon *Commonwealth* Aug. 17. [7] Madison *Union* Aug. 15. [8] Madison *State Journal* Aug. 15. [9] S. S. G. *Wilkes' Spirit of the Times* 15 (Oct. 6, 1866) 82. [10] Black River Falls *Banner*. In Madison *State Journal* Sept. 19 and Oct. 4. [11] Fond du Lac *Commonwealth* Aug. 19. [12] Milwaukee *Wisconsin* Aug. 15.

## 1867

The year 1867 is the second to show a pronounced scarcity. In May prairie chickens were reported unusually numerous at Beaver Dam,[1] and in August at Stevens Point.[2] Elsewhere the comments stressed scarcity. At Hudson[3] they were "unusually scarce." The question was raised at Prescott[4] if there were "any in the country." The lack of birds was noted at Berlin,[5] Fond du Lac,[6] Burlington,[7] Whitewater,[8] and Madison.[9] Two exceptional daily bags were reported at Madison. One hunter shot 90 and two hunters 75 birds.

The experience of a Racine hunter shows clearly the reduction in numbers. He hunted at Union Grove and saw but two birds before breakfast. He then hunted until noon with two companions, flushing but one flock, thirteen in number, of which twelve were killed. The afternoon was spent at Tar Corners, Kenosha County, where no birds were found.[10]

The phenomenon of scarcity did not escape explanations. Conservative opinion leaned to the old belief in the decimating effect of a cold, wet spring.[11] The weather was not sufficiently lethal for others who advanced the theory that the birds had died from eating potato bugs.[12] Disease usually does not work with simultaneous severity over an area the size of a commonwealth, but it is interesting to note that prairie chickens, this season, were reported scarcer in Iowa than for years.[13] In June of this year, J. A. Allen[14] made observations on the birds of Ogle County, Illinois, that is on the Wisconsin boundary. His comment on the prairie chicken, "more or less abundant on the prairie," is not highly informative.

[1] Beaver Dam *Citizen* May 2. [2] Stevens Point *Lumberman* Aug. 23. [3] Hudson *Star* and *Times* Aug. 21 and Sept. 4. [4] Prescott *Journal* Sept. 7. [5] Berlin *Courant* Sept. 19. [6] Fond du Lac *Reporter* Aug. 24. [7] Burlington *Standard* Sept. 4. [8] Whitewater *Register*. In Madison *State Journal* Aug. 24. [9] Madison *Union* Aug. 19, 21, 22, and 24; *State Journal* Aug. 23. [10] Racine *Advocate* Aug. 24. [11] Waukesha *Plain Dealer* Sept. 3; Prescott *Journal* Sept. 7. [12] Ref. 62. [13] "Field." *Wilkes' Spirit of the Times* 17 (Nov. 30, 1867) 273. [14] J. A. Allen, *Mem. Bost. Soc. Nat. Hist.* 1 (1868) 506.

## 1868

The recovery this year is difficult to explain on the theory that the sharp drop in 1867 was due to disease. The birds were reported as unusually plentiful at Green Bay[1] where they appeared to be increasing yearly. They were plentiful at Eau Claire[2] and "vast numbers" were killed at Black River Falls.[3] It was estimated that the hunters at Oshkosh[4] secured about 500 birds on the opening day. One party of six men shot 126 birds.[5] The best bag at Fond du Lac[6] was 63 birds secured by a party of four men. Watertown[7] and Shawano[8] reported them plentiful, and Brandon[9] and Madison,[10] fairly plentiful. The price of 30 cents a bird at Madison is indicative of scarcity. Three men from Waukesha,[11] hunting in Walworth County, shot 50 birds the first morning of the season. They were scarce at Prescott[12] and Hudson,[13] in the northwestern part of the state.

[1] Green Bay *Advocate* Aug. 27. [2] Eau Claire *Free Press* Sept. 24. [3] Black River Falls *Banner* Aug. 29. [4] Oshkosh *Times* Aug. 25. [5] Oshkosh *Journal* Aug. 22. [6] Fond du Lac *Reporter* Aug. 29; *Commonwealth* Aug. 26. [7] Watertown *Democrat* Aug. 20 and 27. [8] Shawano *Journal* Aug. 27. [9] Brandon *Times* Aug. 15. [10] Madison *State Journal* Aug. 21 and 22. [11] Waukesha *Plain Dealer* Aug. 25. [12] Prescott *Journal* Aug. 7. [13] Hudson *Star* and *Times* Aug. 19.

### 1869

There was a decrease over the previous year. The only enthusiastic report came from Eau Claire.[1] In general, prairie chickens were considered scarce throughout the state.[2] Complaints of poor shooting issued from Hudson,[3] La Crosse,[4] Black River Falls,[5] Mauston,[6] Shawano,[7] Appleton,[8] Oshkosh,[9] Waupun,[10] Watertown,[11] and Berlin.[12] Data on bags give a good idea of the shooting. A hunting and fishing party of four men drove to the Sand Creek country, 25 miles from Chippewa Falls. The first flock of prairie chickens was encountered after travelling fifteen miles. In a period of two and one-half days, only 15 birds were killed.[13] The best bag obtained on the opening day at Fond du Lac,[14] secured by the united efforts of three men and two dogs, was seven birds. The largest subsequent daily bag, sixteen, was secured by a market hunter.

[1] Eau Claire *Free Press* Aug. 26. [2] Milwaukee *Sentinel* Aug. 31. [3] Hudson *Star* and *Times* Sept. 1. [4] La Crosse *Leader* Aug. 17. [5] Black River Falls *Banner* Sept. 4. [6] Mauston *Star* Aug. 26. [7] Shawano *Journal* Sept. 23. [8] Appleton *Crescent* Sept. 4. [9] Oshkosh *Journal* Aug. 28. [10] Waupun *Leader* Aug. 26. [11] Watertown *Republican* Aug. 25. [12] Berlin *Courant* Sept. 2. [13] Chippewa Falls *Union* and *Times* Aug. 28. [14] Fond du Lac *Reporter* Aug. 28.

### 1870

In general there was a distinct improvement over 1869. The shooting was good at Kenosha[1] on the opening day, but the birds soon became scarce. Jefferson,[2] Mineral Point,[3] and Portage[4] reported them more plentiful than for several years past. They were plentiful at Columbus,[5] while the shooting at Fond du Lac[6] was better on the opening day than the year previous. The shooting was "fair" at Kilbourn,[7] Waupun,[8] and Janesville.[9] At Oshkosh,[10] a party of six hunted at Rosendale on the opening day and secured 60 birds. "Six to ten birds in an afternoon's tramp is about the average in this immediate vicinity."

They were scarce at Appleton.[11] The shooting in Dane County was relatively poor though 100 birds were reported to have been shot in the town of Albion prior to the opening of the season.[12] An experienced hunter secured but 30 birds in two days.[13]

Prairie chickens were quite plentiful in the northwestern portion of the state. At La Crosse[14] one man shot 50 birds in less than half a day, while another is credited with killing 250 during the season. They were plentiful at Eau Claire[15] and Hudson.[16] They were reported plentiful also in Chippewa County.[17] The data available are conflicting. Four men hunted for a day at Hay Creek and secured only 30 birds; but one man is stated to have killed 13 in four hours.[18]

They were scarce in the Milwaukee market where the price ranged from $3.25 to $3.50 per dozen the first of September. On November 14, the price was $4.00.[19]

[1] Kenosha *Telegraph* Aug. 25, Sept. 1 and 15. [2] Jefferson *Banner* Aug. 24. [3] Mineral Point *Tribune* Aug. 11. [4] Portage *Register* Aug. 27. [5] Columbus. In Madison *State Journal* Aug. 22. [6] Fond du Lac *Reporter* Aug. 27. [7] Kilbourn *Mirror* Aug. 25. [8] Waupun *Leader* Aug. 25 and Sept. 8. [9] Janesville *Gazette* Aug. 19. [10] Oshkosh *Journal* Aug. 27. [11] Appleton *Crescent* Aug. 13 and Sept. 3. [12] Madison *State Journal* Aug. 2. [13] Madison *Democrat* Oct. 6. [14] La Crosse *Leader* Aug. 27, Oct. 8 and Dec. 10. [15] Eau Claire *Free Press* Oct. 20. [16] Hudson *Star* and *Times* Aug. 26. [17] Chippewa Co. In Madison *State Journal* Aug. 19, (1). [18] Chippewa Falls *Herald* Aug. 20 and 27. [19] Milwaukee *Sentinel* Nov. 14.

### 1871

There were fewer birds than last year. Reports of scarcity came from Racine,[1] Kenosha,[2] Burlington,[3] Columbus,[4] Portage,[5] Waupun,[6] Watertown,[7] Fox Lake,[8] Appleton,[9] Weyauwega,[10] and Sparta.[11] The best day's bag at Fond du Lac[12] was 12 birds to two hunters. At Neillsville,[13] the shooting of 40 birds by two men was "flattering success."

A party of Milwaukee hunters shot about 100 birds at New Lisbon.[14] They were quite plentiful at Elkhorn,[15] Janesville,[16] Madison,[17] Oshkosh,[18] Mauston,[19] Osceola,[20] and Hudson.[21] A few localities, Brandon,[22] Menomonie,[23] and Black River Falls,[24] reported them more plentiful than usual. They appear to have been abundant in Chippewa County where "thousands" were said to have been killed.[25] A party of eight Milwaukee hunters secured 267 birds fourteen miles north of Chippewa Falls.[26]

[1] Racine *Advocate* Aug. 26. [2] Kenosha *Telegraph*, Aug. 24. [3] Burlington *Standard* Aug. 31. [4] Columbus *Democrat* Aug. 25. [5] Portage *Register* Aug. 26. [6] Waupun *Leader* Aug. 25. [7] Watertown *Republican* Aug. 23. [8] Fox Lake *Representative* Aug. 25. [9] Appleton *Crescent* Sept. 2. [10] Weyauwega *Times* Aug. 26. [11] Sparta *Herald* Aug. 8. [12] Fond du Lac *Reporter* Aug. 26. [13] Neillsville *Republican* Sept. 20. [14] New Lisbon *Argus* Aug. 31. [15] Elkhorn *Independent* Sept. 13. [16] Janesville *Gazette* Aug. 21. [17] Madison *Democrat* Aug. 17. [18] Oshkosh *Journal* Aug. 26. [19] Mauston *Star* July 20. [20] Osceola *Press* Aug. 18. [21] Hudson *Star* and *Times* Aug. 4, 11 and 25. [22] Brandon *Times* June 21. [23] Menomonie *News* Sept. 23. [24] Black River Falls *Banner* July 22 and Nov. 4. [25] Chippewa Falls *Herald* Sept. 2 and 9. [26] Milwaukee *News* Sept. 1.

### 1872

There was some improvement this year. Prairie chickens were scarce at Janesville,[1] Watertown,[2] Brandon,[3] Fond du lac,[4] Waupaca,[5] Mineral Point,[6] and New Lisbon.[7] They were fairly numerous to plentiful at Waukesha,[8] Burlington,[9] Lodi,[10] Columbus,[11] Friendship,[12] Mauston,[13] Black River Falls,[14] Augusta,[15] Menomonie,[16] and Oshkosh.[17] A party of Oshkosh hunters shot 98 birds on the opening day.

Prairie chickens were exceptionally plentiful in St. Croix County in April, but after a hail storm in August, very few were to be found.[18] They were unusually plentiful at Hudson,[19] and sufficiently numerous in some parts of Eau Claire County to be considered a pest to the farmers.[20] Eau Claire sportsmen, during the first part of the season, secured about 300 birds daily.

[1] Janesville *Gazette* Aug. 19 and 29. [2] Watertown *Republican* July 31. [3] Brandon *Times* Aug. 16. [4] Fond du Lac *Reporter* Aug. 24. [5] Waupaca. In Milwaukee *J. Commerce* Sept. 4. [6] Mineral Point *Tribune* Aug. 8. [7] New Lisbon *Argus* Aug. 29. [8] Waukesha *Democrat* Aug. 13. [9] Burlington *Standard* Aug. 29. [10] Lodi *Journal* Sept. 4. [11] Columbus *Republican* Aug. 24. [12] Friendship *Press* Oct. 26. [13] Mauston *Star* Aug. 22. [14] Black River Falls *Banner* Aug. 10. [15] Augusta *Herald* Aug. 31. [16] Menomonie *News* Aug. 3. [17] Oshkosh *Journal* Aug. 24. [18] Hudson *Republican*. In Madison *State Journal* April 27, Aug. 15. [19] Hudson *Star* and *Times* July 26. [20] Eau Claire *Free Press* Aug. 1 and 22.

## 1873

The increase in the number of prairie chickens this season was pronounced in spite of a complaint of scarcity throughout the state.[1] The southeastern section, as usual, had poor shooting. The birds were reported scarce at Watertown,[2] Waterloo,[3] Waupun,[4] Fond du Lac,[5] Brandon,[6] Appleton,[7] Neillsville,[8] and Black River Falls.[9] Two men killed 28 birds in about one half of a day at Elkhorn, where they had been scarce for a dozen years.[10] A Beloit[11] hunter is stated to have killed 19 on the opening day, August 20, and by the 23rd to have made a total bag of 78 birds for the season. This smacks of pre-season practise. There was a decided increase in Dane County.[12] One party of four men killed 105 in fourteen hours, and another party of two shot 75 birds.[13]

The winter of 1872-3 was quite severe. The farmers in St. Croix County reported that it had been extremely hard on the prairie chickens, some being too weak to run or fly. Hunger had driven them closer to their dwellings than usual and numbers had been fed in the barnyards; however, many had died of starvation, so that it was probable that the "crop" would be a failure. This fear does not seem to have been realized since at Kinnickinnic, in August, prairie chickens were "thicker than politicians."[14] The scarcity at Brandon[6] was attributed not only to the severity of the winter, but to the killing of the young by the cold, wet spring. Other localities in the state reported that the birds were plentiful in spite of the winter.

They were exceptionally numerous, or abundant, at Oshkosh,[15] Fox Lake,[16] Beaver Dam,[17] Menasha,[18] Dodgeville,[19] Chippewa Falls,[20] Durand,[21] Ellsworth,[22] and La Crosse.[23]

In July, thousands of young prairie chickens were reported in the vicinity of Osseo,[24] Trempealeau County. In August, a hunting party from Eau Claire killed 246 young birds in two days near Osseo.[25] T. S. and a companion shot 75 birds in two days in Trempealeau County. He was of the opinion that they were becoming wilder and less plentiful every year.[26]

A party of six hunters from Eau Claire drove to the headwaters of Pine Creek, Barron County, and camped in Town 33, Range 12. Over 150 birds were shot in one day. The total number of "chickens" and "grouse" secured was 364. It was estimated that 100 birds were not found owing to the thick brush on some of the ground.[27]

The middle of August, prairie chickens sold at $2.25 per dozen at Prairie du Chien.[28] The Milwaukee market was supplied abundantly. Owing to the unfavorable weather, they were "nearly unsaleable," and large quantities were thrown away.[29]

[1] Milwaukee *News* Sept. 23. [2] Watertown *Republican* Aug. 20. [3] Waterloo *Journal* Aug. 23. [4] Waupun *Leader* Aug. 22 and 29. [5] Fond du Lac *Reporter* Aug. 9 and 23. [6] Brandon *Times* Aug. 15. [7] Appleton *Crescent* Aug. 30. [8] Neillsville *Press* Aug. 15. [9] Black River Falls *Banner* Aug. 30. [10] Elkhorn. In Burlington *Standard* Sept. 4. [11] Beloit *Free Press* Aug. 23. [12] Madison *Democrat* Aug. 29, Sept. 1, 6, and Oct. 10. [13] Madison *State Journal* Aug. 22 and 28. [14] Hudson *Star* and *Times* April 11 and Aug. 29. [16] Oshkosh *Times* Aug. 13. [15]Madison *State Journal* Aug. 6. [17] Beaver Dam *Argus* Aug. 14. [18] Menasha *Press* Aug. 11. [19] Dodgeville *Chronicle* Aug. 22. [20] Chippewa Falls *Herald* Aug. 15, Sept. 6. [21] Durand *Times* July 18. [22] Ellsworth *Herald* Aug. 6, Sept. 3. [23] La Crosse *Democrat*. In Milwaukee *News* Oct. 11. [24] Eau Claire *Free Press* July 17. [25] Eau Claire *Herald* Aug. 23. [26] T. S. *Forest and Stream*, 1, No. 6 (Sept. 18, 1873) 83. [27] Eau Claire *Herald* Sept. 4. [28] Prairie du Chien *Courier* Aug. 19. [29] Milwaukee *Sentinel* Aug. 23, 25.

## 1874

Prairie chickens increased again. In February, they were "extremely plentiful" on the bluffs near Eau Claire.[1] In the autumn, though Racine[2] had but few birds, there were unusual numbers in the southeastern portion of the state. This was true at Sharon,[3] Janesville,[4] Watertown,[5] Green County,[6] Waupun,[7] and Fox Lake.[8] A hunter at Elkhorn[9] killed 21 birds before breakfast. The shooting was poor at Madison[10] and Beaver Dam.[11] There was exceptionally good sport at Omro,[12] Montello,[13] and Stevens Point.[14] At Oshkosh[15] some hunters killed 20 birds a day. Six Waupaca[16] hunters spent a week end in Portage County and, in spite of two days of rain, shot 80 prairie chickens.

There was good hunting at Kilbourn[17] and vicinity. Two men secured 55 birds in a day's hunt in the town of Excelsior, Sauk County,[18] while H. M. Butterfield shot about 200 birds from August 15 to September 9 in the town of Fairfield.[19]

In the northwestern portion of the state Sparta,[20] River Falls,[21] and Ellsworth[22] reported poor shooting, but it was good at Black River Falls.[23] Chippewa County claimed to have the best hunting in the west.[24] One party of two men from Green Bay shot 150 birds near Alma Center, Jackson County, while another party of two obtained 240 at Pleasant Valley, Trempealeau County.[25] At Durand,[26] two men shot over 50 birds in a day's hunt.

In September, prairie chickens sold at $2.25 to $2.50 a dozen in Milwaukee.[27]

[1] Eau Claire *Free Press* Feb. 12. [2] Racine *Journal* Aug. 19. [3] Sharon *Inquirer* Sept. 10. [4] Janesville *Gazette* Aug. 26. [5] Watertown *Democrat* Aug. 27. [6] Madison *Democrat* Aug. 22. [7] Waupun *Leader* Aug. 28. [8] Fox Lake *Representative* Aug. 21. [9] Elkhorn *Independent*. In Madison *State Journal* Sept. 4. [10] Madison *State Journal* Aug. 18, 21. [11] Beaver Dam *Citizen* Aug. 27. [12] Omro *Journal* Aug. 20. [13] Montello *Express* Aug. 22. [14] Stevens Point *Journal* Aug. 29. [15] Oshkosh *Times* Sept. 2. [16] Waupaca *Republican* Aug. 27. [17] Kilbourn *Mirror* Sept. 4. [18] Reedsburg *Free Press* Aug. 20. [19] Baraboo *Republic* Sept. 9. [20] Sparta *Herald* Aug. 5. [21] River Falls *Press* Aug. 20, 27, Oct. 8. [22] Ellsworth *Herald* Sept. 2. [23] Black River Falls *Banner* Aug. 15. [24] Chippewa Falls *Herald* Aug. 14, 21. [25] Green Bay *Advocate* Aug. 27, Sept. 3. [26] Durand *Times* Aug. 21. [27] Milwaukee *Sentinel* Sept. 9.

## 1875

The population continued at a good level. The spring reports on the status of the prairie chicken were very favorable though the winter of 1874-5 was severe;[1] however, in two localities a considerable decrease was attributed to the weather.[2] When the season opened, the reports, though mixed, were largely favorable.

In the southeastern section, the shooting was good at Mukwanago, Waukesha County,[3] Janesville,[4] and Burlington.[5] Near Delavan[6] one man shot 35, and two men 20 birds, on August 16. Several hundred were reported shot near Lake Geneva[7] during the first week of the open season. The shooting was very good in Dane County. Four men from Madison returned with 153 prairie chickens from York Prairie, town of York, where they hunted three days, presumably. Three men hunting on Swanton's Marsh, town of Cottage Grove, shot 29 birds in about an hour.[8] The other large bags reported were made probably in Iowa.[9] There were few birds at Stoughton,[10] and so few near

Kenosha[11] that the end of the species in Kenosha and Racine Counties seemed to be in sight.

They were plentiful to abundant at Berlin,[12] Oshkosh,[13] Menasha,[14] and Wausau.[15] Pond,[16] who resided at Montello, reported "grouse" more plentiful than the year previous. Two men shot 36 birds in a day. They were abundant at Stevens Point[17] where three men killed 65 on August 15. The following day two men bagged 85. They were plentiful also at Wautoma[18] where a party is stated to have killed about 400 in a period of ten days. The reports from Waupun[19] varied. The birds were scarce at Manitowoc,[20] Brandon,[21] Ripon,[22] and Fond du Lac.[23]

In most of the western portion of the state prairie chickens were not plentiful. They were scarce at New Lisbon,[24] Viroqua,[25] and Black River Falls.[26] Prairie chickens were reported plentiful at Prairie du Chien,[27] Rice Lake,[28] and Sparta,[29] where three men shot "about forty-five" in a few hours. In St. Croix County they were scarce,[30] though two men shot 89 birds in a day's hunt.[31] Three men hunting in Buffalo County secured over 100 birds.[32] The shooting in Pierce County was reported poor to good.[33]

[1] Milwaukee *Sentinel* May 13, (1); New Richmond *Republican* April 14; Boscobel *Dial* March 19; Waupun *Times* May 11. [2] Fred (Pond), *Rod and Gun* 6 (April 3, 1875) 10; Waukesha *Democrat* March 13. [3] Waukesha *Freeman* Sept. 2; *Democrat* Sept. 11. [4] Janesville *Gazette* Aug. 18, 24. [5] Burlington *Standard* Aug. 19. [6] Delavan *Republican* Aug. 19. [7] Lake Geneva *Herald* Aug. 21. [8] Madison *State Journal* Aug. 18, 24, Sept. 11. [9] Madison *Democrat* Aug. 17, 21, 29, Sept. 1. [10] Stoughton. In Milwaukee *Com. Times* Aug. 13. [11] Kenosha *Union* Aug. 12, 26. [12] Berlin *Courant* Aug. 28. [13] Oshkosh *Times* July 31, Aug. 21; *Northwestern* Aug. 26. [14] Menasha *Press* Aug. 26, Sept. 2. [15] Wausau *Pilot*, Aug. 21. [16] Fred (Pond), *Rod and Gun* 6 (Aug. 28, 1875) 323; Montello *Express* July 17. [17] Stevens Point *Journal* July 31, Aug. 21. [18] Wautoma *Argus* Aug. 11, 25. [19] Waupun *Leader* Aug. 27; *Times* May 11, Aug. 31. [20] Manitowoc *Pilot* Sept. 2. [21] Brandon *Times* Aug. 19, Sept. 2. [22] Ripon *Free Press* Aug. 19. [23] Fond du Lac *Reporter* Aug. 21; *Journal* Sept. 16. [24] New Lisbon *Argus* Aug. 26. [25] Viroqua *Censor* Aug. 11. [26] Black River Falls *Banner* Aug. 7. [27] Prairie du Chien *Union* Aug. 20. [28] Rice Lake *Chronotype* Aug. 7. [29] Sparta *Herald* Aug. 17. [30] Hudson *Star and Times* Aug. 13; New Richmond *Republican* Aug. 4, 18; Hammond *Independent* Aug. 20. [31] Hudson *Republican* Aug. 25. [32] Eau Claire *Free Press* Aug. 26. [33] River Falls *Advance* Aug. 24; *Press* Aug. 19.

### 1876

The population declined this year. Prairie chickens were unusually plentiful in St. Croix County[1] in April. In the autumn the shooting was poor at Waukesha,[2] Palmyra,[3] Monroe,[4] Waterloo,[5] Waupun,[6] Brandon,[7] Oshkosh,[8] Omro,[9] Winneconne,[10] Berlin,[11] Wautoma,[12] and New London.[13] The largest daily bag at Delavan[14] was 12 birds for two men. One hunter secured 90 between August 15 and September 22. They were scarce at Kilbourn[15] though a party of three men shot 52 on Grand Marsh. Modest bags were made at Madison[16] at the beginning of the season but shortly afterwards there were many complaints of scarcity.[17] Grand Rapids[17a] had fewer birds than the year previous.

They were "quite plentiful" at Prairie du Chien.[18] Sparta[19] reported them more numerous than in 1875, but not nearly as plentiful as in former years. Three men shot 70 birds on the opening day; however, two "boss hunters" returned with only two birds.[20] At New Lisbon,[21] three men shot 75 in one day. They were scarcer at New Richmond,[22] than "was ever known before." Though reported scarce at Trempealeau,[23] a party of Milwaukee hunters obtained 300 birds at Osseo, Trempealeau County.[24] The annual hunt by Eau Claire[25] sportsmen yielded "about two hundred chickens"; and five men are credited with killing 193 at Mondovi, Buffalo County.[26] In the absence of data on the number of hunters and the time spent in the field, it is impossible to draw any conclusions from the numbers killed. The birds were "quite plenty" at Chippewa Falls.[27]

[1] New Richmond *Republican* April 19; Hudson *Star* and *Times* April 21. [2] Waukesha *Democrat* Aug. 26. [3] Palmyra *Enterprise* Aug. 23. [4] Monroe *Reformer* Aug. 24. [5] Waterloo *Journal* Aug. 24. [6] Waupun *Times* Aug. 29. [7] Brandon *Times* Aug. 17. [8] Oshkosh *Times* Aug. 19; *Northwestern* Aug. 24. [9] Omro *Journal* Aug. 31. [10] Milwaukee *Sentinel* Sept. 5. [11] Berlin *Courant* Aug. 26. [12] Wautoma *Argus* Aug. 24. [13] New London *Times* Aug. 26, Sept. 2. [14] Delavan *Republican* Aug. 25, Sept. 22. [15] Kilbourn *Mirror* Aug. 25, Sept. 8. [16] Madison *Democrat* Aug. 17; *State Journal* Aug. 14, 15, 16. [17] Madison *Patriot* Aug. 19, 23, Sept. 7; *State Journal* Aug. 24, 26. [17a] Grand Rapids *Reporter* Aug. 31. [18] Prairie du Chien *Union* Aug. 29; *cf.* Aug. 22. [19] Sparta *Herald* Aug. 15. [20] Sparta *Greenback* Aug 17. [21] New Lisbon *Argus* Aug. 24. [22] New Richmond *Republican* Aug. 23. [23] Trempealeau *Republican* Aug. 25. [24] Eau Claire (w) *Free Press* Aug. 31. [25] *Ibid.* Aug. 24. [26] *Ibid.* Aug. 24. [27] Chippewa Falls *Times* Aug. 23; *cf.* Aug. 16.

### 1877

The decline continued. Scarcity was reported from Kenosha,[1] Delavan,[2] Clinton,[3] Darlington,[4] Oconomowoc,[5] Watertown,[6] West Bend,[7] Randolph,[8] Baraboo,[9] Weyauwega,[10] and Oshkosh.[11] At the latter place, the average daily bag of 33 hunters was 7.6 birds.[11a] All the reports from the county of Fond du Lac stressed scarcity.[12] The birds were scarce at Burlington[13] where the three highest bags obtained on the opening day averaged 11 birds per man. One hunter at Dodgeville[14] shot 17 the first day. An exceptionally large number of prairie chickens was observed at Madison,[15] in March, in the vicinity of Nine Springs and Dead Lake (Wingra). In the fall, the shooting was good.[16]

The hunting was good also at Kilbourn.[17] Two men hunting in Waushara County are stated to have killed 80 in one day.[18] A party hunting at Grand Rapids shot 65 one day, mainly between 3:00 and 5:00 P.M. The marsh is described.[19]

They were reported "quite plenty" at Prairie du Chien,[20] and more numerous than for several years at Viroqua.[21] Arcadia[22] considered them abundant. The average of eleven bags reported at Sparta[22a] on the opening day was 5.9 birds per man. At Tomah,[23] two men killed 26 "grouse" in two hours. They were scarce at New Lisbon,[24] Galesville,[25] Hudson,[26] and Rice Lake.[27]

They were quite plentiful at River Falls,[28] "ten or fifteen chickens to an afternoon being the usual bag of a brace of hunters." Conditions were less favorable in Jackson County. A party of nine hunters, camping in the northwestern part, killed 105 birds in four days. This represents a kill of only 3 birds per man per day. Another party of five men, hunting at Pigeon Creek, secured about 22 birds.[29] In Chippewa County, they were reported numerous near Chippewa Falls, but not at Bloomer.[30] Prairie chickens were not only plentiful during the hunting season near La Crosse, but in November were to be found by hundreds in the cornfields where they were being trapped.[31]

All the reports for Barron County indicate that they were unusually plentiful.[32] A fishing and hunting party that spent a day at Pine Creek in this county, took 70 birds and 100 trout.[33] The most favorable reports came from Eau Claire.[34] A party of eight men in four days killed 143 birds at the junction of Big Creek and Beef River.[35] Taking into consideration three additional specific bags,[36] the average per man for a full day was 9 birds. This does not indicate a very high population.

[1] Kenosha *Telegraph* Aug. 30. [2] Delavan *Republican* Aug. 24. [3] Clinton *Independent* Aug. 22. [4] Darlington *Republican* Aug. 24. [5] Oconomowoc *Free Press* Aug. 25. [6] Watertown *Republican* Aug. 29. [7] West Bend *Democrat* Aug. 22. [8] Randolph *Times* Aug. 31. [9] Baraboo *Republic* Aug. 8. [10] Weyauwega *Chronicle* Sept. 1. [11] Oshkosh *Times* Aug. 18. [11a] Oshkosh *Northwestern* Aug. 23. [12] Fond du Lac *Commonwealth* Aug. 18; Brandon *Times* Aug. 23, Sept. 6; Ripon *Press* Aug. 23; Waupun *Leader* Aug. 17, 31; *Times* Aug. 21. [13] Burlington *Standard* Aug. 16. [14] Dodgeville *Chronicle* Aug. 17. [15] Madison *Democrat* March 18. [16] Madison *State Journal* Aug. 16 and *Democrat* Aug. 17. [17] Kilbourn *City Guard* Aug. 22, Sept. 5. [18] Green Bay *Advocate* Sept. 20. [19] Milwaukee *Sentinel* Aug. 18. [20] Prairie du Chien *Courier* Sept. 4. [21] Viroqua *Censor* Oct. 3. [22] Merrillan *Leader* Sept. 15. [22a] Sparta *Republican* Aug. 17. [23] Tomah *Journal* Aug. 18. [24] New Lisbon *Argus* Aug. 30. [25] Galesville *Independent* Aug. 30. [26] Hudson *Star* and *Times* Aug. 10, 17, 24. [27] Rice Lake *Chronotype* Sept. 13. [28] River Falls *Press* Aug. 16, 29, Sept. 6. [29] Black River Falls *Independent* Aug. 22, 29. [30] Chippewa Falls *Herald* July 20, Sept. 14; *Times* Sept. 12. [31] I. S. F., *Forest and Stream* 9 (Dec. 6, 1877) 355. [32] Eau Claire *Free Press* July 26, Aug. 23;

Chippewa Falls *Times* Aug. 15. [33] Menomonie *News* Aug. 25. [34] Eau Claire (w) *Free Press* Aug. 23, Sept. 6; Chippewa Falls *Herald* Sept. 7. [35] Eau Claire (w) *Free Press* Aug. 30. [36] *Ibid.* (d) Aug. 30.

## 1878

This year was another decided low. The reports of scarcity are so numerous and state-wide that it is unnecessary to report upon localities.[1] At Neillsville[2] it was said that "the truth is becoming enforced upon old sportsmen that their favorite sport is about at an end forever in these parts."

A few good bags are recorded. At Oshkosh[3] two men killed 19 birds before 10 A.M. and three men shot 42 in a day's hunt. One man at Waupun[4] shot 42 in a day. Another hunter is credited with killing 188 in four days in Green Lake County.[5] At Neenah[6] three men shot 25 in two hours. A Portage[7] hunter secured 24 birds in one day, while at Lodi[8] 21 were shot by two men. The two highest individual bags at Madison[9] were 19 and 33 birds. The few reports from Eau Claire[10] show an average daily kill of 7.4 birds. Large numbers were reported killed in the lowlands in the vicinity of Tomah[11] during a period of a few days.

Several dozen were shipped from Arena,[12] Iowa County, for which $4.00 per dozen was paid. As for the Milwaukee[13] market, it was stated: "Prairie chickens and quality are rarely seen."

[1] Racine *Advocate* Aug. 31 and *Journal* Aug. 28; Burlington *Standard* Sept. 7; Lake Geneva *Herald* Aug. 31, Sept. 14; Janesville *Times,* Aug. 8; Watertown *Democrat* Aug. 29; Edgerton *Reporter* Aug. 23; Columbus *Democrat* Aug. 31; Baraboo *Republic* Sept. 11; Friendship *Press* Oct. 12; Ripon *Free Press* Aug. 29; Waupun *Leader* Aug. 30; Waupaca *Post* Oct. 19; Brandon *Times* Sept. 5; Fond du Lac *Reporter* Sept. 5 and *Commonwealth* Aug. 31, Sept. 21; Oshkosh *Northwestern* Sept. 5; Winneconne *Item* Aug. 31; Neenah *Gazette* Aug. 3; Shawano *Journal* Sept. 28; Stevens Point *Journal* Aug. 31; New Lisbon *Argus* Sept. 5, 19; Sparta *Democrat* Aug. 31; River Falls *Journal* Sept. 12, 19; Chippewa Falls *Times* Aug. 21; Black River Falls *Banner* Sept. 13; Merrillan *Leader* Aug. 30; Galesville *Independent* Sept. 19. [2] Neillsville *Republican* and *Press,* Aug. 30. [3] Oshkosh *Times* Aug. 31; *Northwestern* Sept. 5. [4] Waupun *Leader* Aug. 30. [5] Juneau *Democrat* Sept. 11. [6] Oshkosh *Northwestern* Aug. 29. [7] Portage *Democrat* Aug. 30. [8] Lodi *Valley News* Aug. 28. [9] Madison *Democrat* Aug. 27; *cf.* Aug. 29. [10] Eau Claire *Free Press* Aug. 29. [11] Tomah *Journal* Aug. 31. [12] Arena *Star* Aug. 30. [13] Milwaukee *Sentinel* Aug. 28.

## 1879

Prairie chickens were reported scarce in nineteen localities.[1] Several pre-season statements that they were plentiful were not substantiated subsequently. The season at Madison[2] was fairly successful taking into consideration the decline in "opportunitities." Improved shooting, or an increase in the number of birds was reported from Ripon,[3] Pewaukee,[4] Monroe,[5] Darlington,[6] and Mineral Point.[7] Racine[8] had few birds, but five men shot 30, and two men 27, on the opening day. At Delavan,[9] three men shot 23 birds, while at Lake Geneva[10] two parties of three men each secured 21 and 20, respectively. For the opening days, the best bag recorded for the state was 36 birds, shot near Fond du Lac[11] by two hunters.

[1] Racine *Advocate* Aug. 30; Lodi. Portage *Register* Sept. 13; Fox Lake *Representative* Aug. 29; Waupun *Leader* Aug. 29; Brandon *Times* Aug. 28; Fond du Lac *Commonwealth* Aug. 16, 26; Westfield. Montello *Express* Oct. 4; Oshkosh *Times*, Aug. 30; Appleton *Crescent* Sept. 6; Green Bay *Gazette* Aug. 30; Oconto *Reporter* Sept. 13; Boscobel *Dial* Oct. 31; Tomah *Journal* Aug. 30; Whitehall *Messenger* Sept. 3; Eau Claire *Free Press* Aug. 22, Sept. 4; Menomonie *News* Sept. 13; New Richmond *Republican* Aug. 13; Hudson *Star* and *Times* Aug. 15; River Falls *Journal* Aug. 28; *Press* Aug. 28. [2] Madison *State Journal* Nov. 17. [3] Ripon. Milwaukee *Sentinel* Aug. 26. [4] Pewaukee. Milwaukee *Sentinel* Aug. 27. [5] Monroe *Reformer* July 31. [6] Darlington *Democrat* Aug. 1. [7] Mineral Point *Tribune* Aug. 6. [8] Racine *Journal* Aug. 27. [9] Delavan *Enterprise* Aug. 30. [10] Lake Geneva *Herald* Aug. 29. [11] Fond du Lac *Commonwealth* Aug. 26.

### 1880

The birds were again scarce in some localities, but there was a decided improvement over the year previous. There were few birds at Delavan,[1] Janesville,[2] Fox Lake,[3] Princeton,[4] Oconto,[5] Chippewa Falls,[6] New Richmond,[7] Hudson,[8] River Falls,[9] Arcadia,[10] Alma,[11] and Black River Falls.[12]

They were reported more numerous than usual at Darlington[13] and Juneau,[14] and there was good shooting at Menomonie.[15] A Green Bay hunter shot 28 birds near Peak's Point, these being the only birds offered for sale in the city during the past five years.[16] Another hunter is stated to have shot 48 birds one morning at Stevens Point.[17] The average bag on the opening day at Fond du Lac was 6.8 birds. One hunter killed 80 between August 15 and September 18.[18] At Madison,[19] two men shot 53 in one day. Five men, hunting for a week on Beaver Creek, Eau Claire County, killed 187 birds.[20]

In October, prairie chickens were scarce to absent in the Milwaukee market.[21]

[1] Delavan *Republican* Aug. 27. [2] Janesville *Recorder* Aug. 13, 28. [3] Fox Lake *Representative* Aug. 20. [4] Princeton *Democrat* Sept. 9. [5] Oconto *Reporter* Sept. 18. [6] Chippewa Falls *Herald* Aug. 20; *Times* Aug. 25. [7] New Richmond *Republican* Aug. 25. [8] Hudson *Republican* Aug. 25. [9] River Falls *Journal* Aug. 26; *Press* Aug. 26. [10] Arcadia *Republican and Leader* Aug. 26. [11] Alma *Journal* Aug. 26, Sept. 2. [12] Black River Falls *Banner* Aug. 13. [13] Darlington *Democrat* July 16. [14] Juneau *Telephone* Sept. 3. [15] Menomonie *News* Aug. 21, Sept. 4; *Times* Aug. 6; Milwaukee *Sentinel* Sept. 6. [16] Green Bay *Advocate* Aug. 21. [17] Stevens Point *Pinery*. In Green Bay *Advocate* Aug. 26. [18] Fond du Lac *Commonwealth* Aug. 21, Sept. 18. [19] Madison *Democrat* Aug. 29. [20] Eau Claire (w) *Free Press* Sept. 2. [21] Milwaukee *Sentinel* Oct. 11, 18.

**1881**

In general there were more birds than in 1880. The localities reporting them more numerous than for several years were: Berlin,[1] Montello,[2] Sun Prairie,[3] Mineral Point,[4] Chippewa Falls,[5] and Galesville.[6] Though scarce at Racine,[7] the shooting at Kenosha[8] was exceptional. At the latter place, one man secured 47 birds in a day's hunt, while two men shot 26 in one and one-half days. They were quite numerous to plentiful at Stevens Point,[9] Oshkosh,[10] Ripon,[11] Waterloo,[12] Madison,[13] Bloomer,[14] Durand,[15] and Ellsworth.[16]

Reports of scarcity came from Wautoma,[17] Brandon,[18] Markesan,[19] Waupun,[20] Sparta,[21] Tomah,[22] Pepin,[23] Black River Falls,[24] Menomonie,[25] River Falls,[26] and New Richmond.[27]

[1] Berlin *Courant* Aug. 24. [2] Montello *Express* July 30. [3] Sun Prairie *Countryman* July 28, Aug. 18. [4] Mineral Point *Tribune* Aug. 4, 25. [5] Chippewa Falls *Herald* July 22, Aug. 19. [6] Galesville *Independent* Aug. 18. [7] Racine *Journal* Aug. 24. [8] Kenosha *Courier* Aug. 18. [9] Stevens Point *Gazette* Aug. 24; *Journal* Sept. 3. [10] Oshkosh *Northwestern* Aug. 18; *cf. Times* Aug. 20. [11] Ripon *Free Press* Aug. 18. [12] Waterloo *Journal* Sept. 1. [13] Madison *State Journal* Aug. 23; *Democrat* Aug. 25, 28. [14] Bloomer *Workman* Aug. 18, Sept. 1. [15] Durand *Courier* Aug. 19. [16] Ellsworth *Herald* Aug. 24. [17] Wautoma *Argus* Aug. 26. [18] Brandon *Times* Aug. 18. [19] Markesan *Democrat* Aug. 18, 25. [20] Waupun *Leader* Aug. 19, 26. [21] Sparta *Herald* Aug. 23; *cf. Democrat* Aug. 20. [22] Tomah *Journal* Aug. 20. [23] A. T., *Am. Field* 16 (Oct. 22, 1881) 265. [24] Black River Falls *Banner* Sept. 2. [25] Menomonie *News* Aug. 20; *Times* Aug. 19, Sept. 2. [26] River Falls *Press* Aug. 25. [27] New Richmond *Republican* Aug. 31.

**1882**

The improvement seems to have continued. The pre-season predictions were very optimistic from Necedah,[1] Eau Claire,[2] La Crosse,[3] River Falls,[4] and New Richmond.[5] While not abundant at Black River Falls,[6] prairie chickens were more numerous than for "the past two years." The shooting was good at Grand Rapids,[7] where four men secured 45 birds in one half of a day. They were reported quite plentiful to numerous at Beloit,[8] Waupaca,[9] Markesan,[10] Chippewa Falls,[11] Menomonie,[12] Hudson,[13] River Falls,[14] and New Lisbon.[15]

The shooting was poor to indifferent at Lake Geneva,[16] Janesville,[17] Waupun,[18] Brandon,[19] Oshkosh,[20] Montello,[21] Menasha,[22] and in Barron County.[23]

[1] Necedah *Signal* June 29. [2] C. M. B. *Am. Field* 18 (July 29, 1882) 78. [3] La Crosse (w) *News* June 4. [4] River Falls *Press* April 13. [5] New Richmond *Republican* May 31. [6] Black River Falls *Banner* Aug. 18. [7] Grand Rapids *Reporter* Aug. 17, 31. [8] Beloit *Outlook* Aug. 19; *cf. Free Press* Sept. 11. [9] Waupaca *Republican* Aug. 18. [10] Markesan *Democrat* Aug. 24. [11] Chippewa Falls *Independent* Aug. 24; *Herald* Sept. 15; *cf.* Bloomer *Workman* Aug. 31. [12] Menomonie *Times* Aug. 18. [13] Hudson *Star* and *Times* Aug. 18. [14] River Falls *Journal* Aug. 24. [15] New Lisbon *Argus* Aug. 24. [16] Lake Geneva *Herald* Aug. 18. [17] Janesville *Recorder* Aug. 25; *Gazette* Aug. 24, Sept. 1. [18] Waupun *Leader* Aug. 25. [19] Brandon *Times* Aug. 31. [20] C. M. B. *Am. Field* 18 (Sept. 16, 1882) 198. [21] Montello *Sun* Aug. 19. [22] Menasha *Press* Aug. 24. [23] Chippewa Falls *Times* July 19.

### 1883

The spring reports were encouraging. Prairie chickens were reported quite abundant at Dodgeville.[1] At Columbus on February 21, a flock of 150 was feeding in standing corn.[2] Both pinnated and sharp-tailed grouse were "very abundant" at Necedah,[3] while prairie chickens were more plentiful than usual at Merrillan[4] and Eau Claire.[5]

When the season opened the shooting was poor at Racine,[6] Lake Geneva,[7] Beloit,[8] Wautoma,[9] Princeton,[10] Brandon,[11] Markesan,[12] Rosendale,[13] Oshkosh,[14] Necedah,[15] Mauston,[16] Sparta,[17] and Galesville.[18] The reports from Black River Falls[19] were contradictory. This is the case also with Eau Claire.[20] A party that varied in number from five to ten men over a period of ten days killed 290 birds at Rock Creek.

They were reported numerous to exceptionally plentiful at Westfield,[21] Chippewa Falls,[22] Arcadia,[23] Barron,[24] Prescott,[25] River Falls,[26] and Hudson.[27] It is of exceptional interest that "prairie chickens" were reported quite plentiful near Superior[28] where a hunter shot 15 one day. These may have been sharp-tailed grouse.

[1] Dodgeville *Chronicle* March 23. [2] *Am. Field* 19 (March 10, 1883) 170. [3] C. W. W. *Ibid.* p. 230. [4] E. E. M. *Ibid.* p. 251. [5] C. M. B. *Ibid.* p. 299. [6] Racine *Journal* Aug. 22. [7] Lake Geneva *Herald* Aug. 17. [8] Beloit *Free Press* Aug. 15, 16; *Forest and Stream* 21 (Nov. 29, 1883) 349. [9] Wautoma *Argus* Aug. 24. [10] Princeton *Republic* Aug. 30. [11] Brandon *Times* Aug. 23. [12] Markesan *Democrat* Aug. 23. [13] S. B. Dilley, *Am. Field* 20 (Sept. 1, 1883) 198. [14] Oshkosh *Northwestern* Aug. 23. [15] *Am. Field* 20 (Sept. 15, 1883) 243. [16] Mauston *Star* Aug. 23. [17] Sparta *Herald* Aug. 21. [18] Galesville *Independent* Sept. 3. [19] Black River Falls *Banner* Aug. 17; *Independent* Aug. 29. [20] Eau Claire (d) *Leader* Aug. 17, 22; (w) *Free Press* Aug. 23, 30, Oct. 4; *Am. Field* 20 (Aug. 18, 1883) 150. [21] *Am. Field* 20 (Sept. 22, 1883) 270. [22] Chippewa Falls *Herald* July 27; *Independent* Sept. 20; *Times* July 18, 25, Aug. 1. [23] Arcadia *Republican and Leader* Aug. 3. [24] Barron *Shield* Aug. 24. [25] Prescott *Plaindealer* Aug. 24. [26] River Falls *Journal* Aug. 30, Sept. 13. [27] Hudson *Republican* Aug. 29. [28] Superior *Times* Aug. 25.

### 1884

The birds were somewhat more numerous this year. Reports of scarcity came from Brandon,[1] Princeton,[2] Berlin,[3] Dodgeville,[4] Sparta,[5] Grantsburg,[6] and Menomonie.[7] The statements from Chippewa Falls[8] were contradictory. At Menomonie[9] the most successful parties of four hunters did not secure over 40 birds during a long day's hunt. Though considered scarce at Racine,[10] three men killed 39 birds one day on Barnes Prairie. At Plainfield[11] five hunters had 27 in the day's bag, while at Wautoma[12] a man had 14 birds in illegal possession. The situation in the eastern portion of the state is covered by the report from Madison.[13] While a "trifle" more numerous than usual, it has been years since they were really plentiful in the vicinity, so that most sportsmen have been doing their hunting in Dakota and Minnesota.

Prairie chickens were plentiful at River Falls[14] and Chetek.[15] Hunters at Black River Falls[16] averaged "ten to twenty" birds daily. A hunter at Prescott[17] shot 15 birds in three hours. The best bag made at Eau Claire[18] consisted of 36 birds secured by two men hunting part of a day. Appleton[19] had more birds than for a number of years.

[1] Brandon *Times* Aug. 21. [2] Princeton *Republic* Aug. 28. [3] Berlin *Courant* Aug. 27. [4] Dodgeville *Sun* Aug. 22. [5] Sparta *Herald* Aug. 19. [6] Grantsburg *Sentinel* Aug. 29. [7] (Eau Galle). Menomonie *News* Aug. 23. [8] Chippewa Falls *Times* Aug. 13; *Herald* Aug. 29. [9] B. A. E. *Forest and Stream* 23 (Oct. 2, 1884) 186. [10] Racine *Journal* Aug. 20. [11] Plainfield *Sun* Aug. 22. [12] Wautoma *Argus* Aug. 22. [13] Madison *State Journal* Sept. 20. [14] (Oak Grove). River Falls *Journal* Oct. 9. [15] Chetek *Alert* Sept. 6, 13. [16] Neillsville *Republican and Press* Aug. 28. [17] Prescott *Plaindealer* Aug. 29. [18] Eau Claire (d) *Leader* Aug. 23. [19] Appleton *Post* Sept. 4.

**1885**

There was again some improvement in number. Adverse reports came from Elkhorn,[1] Mineral Point,[2] Dodgeville,[3] Berlin,[4] Mauston,[5] Sparta,[6] Menomonie,[7] Neillsville,[8] and New Richmond.[9]

Prairie chickens were reported abundant, or more numerous than usual at Monroe,[10] Portage,[11] Wautoma,[12] Durand,[13] Chippewa Falls,[14] Barron,[15] River Falls,[16] Hudson,[17] and Grantsburg.[18] Six Portage[19] hunters shot 70 birds in one day near Packwaukee. Two Green Bay[20] hunters returned from Trempealeau Valley with about 100 birds. At Alma,[21] five men shot about 60 birds in three days.

Prairie chickens were again reported "plentiful and much hunted" at Superior.[22] They were reported also to have made their first appearance in Forest County.[23]

[1] Elkhorn *Independent* Aug. 20. [2] Mineral Point *Tribune* Aug. 20; *cf. Democrat* July 10. [3] Dodgeville *Star* Aug. 28. [4] Berlin *Journal* Sept. 3. [5] Mauston *Sun* Sept. 4. [6] Sparta *Herald* Aug. 18. [7] Menomonie *News* Aug. 15. [8] Neillsville *Times* Aug. 25. [9] New Richmond *Republican* Aug. 26, Oct. 7. [10] Monroe *Independent* July 25. [11] Portage *Register* Aug. 15. [12] Wautoma *Argus* Aug. 21. [13] (Waukeek). Durand *Courier* Sept. 4. [14] Chippewa Falls *Times* Aug. 19; *Herald* Aug. 21, Sept. 11. [15] Barron *Shield* Aug. 21. [16] River Falls *Journal* May 7, Aug. 27, Nov. 12. [17] Hudson *Star* and *Times* Aug. 21. [18] Grantsburg *Sentinel* Oct. 30. [19] Portage *Register* Aug. 22. [20] Green Bay *Advocate* Sept. 3. [21] Alma *Journal* Aug. 20. [22] Superior *Times* Sept. 12. [23] Crandon *Forest Leaves* Dec. 3.

### 1886

This year was definitely a high for the cycle and heavy infestation by ticks is reported for the first time.[1] In March, prairie chickens were unusually numerous at Menomonie,[2] and at Black River Falls.[3] They were "quite abundant" at Montello, but probably outnumbered by ruffed grouse.[4] At New Lisbon,[5] a hunter secured 20 birds in a morning, while at Weyauwega[6] four men secured 60 in a day's hunt. Two parties of four men each, hunting at Plover on August 16, secured 28 and 29 birds respectively.[7] The postmaster at Blair, Trempealeau County, is stated to have shot 84 during the first five days of the season.[8] They were reported plentiful at Portage,[9] Prairie du Chien,[10] Merrillan,[11] Chippewa Falls,[12] and Grantsburg.[13]

They were reported scarce at Elkhorn,[14] Mineral Point,[15] Prairie du Sac,[16] Viroqua,[17] Menomonie,[18] and Prescott.[19]

[1] "Greener," *Am. Field* 26 (Sept. 11, 1886) 245. [2] "Wing Shot," *ibid.* p. 316. [3] G. J. S. *Forest and Stream* 26 (April 8, 1886) 207. [4] (Fred Pond), Montello *Express* Aug. 7, (2). [5] New Lisbon *Argus* Aug. 20. [6] Waupaca *Republican* Aug. 20. [7] "Greener," *Am. Field* 26 (Sept. 11, 1886) 245. [8] La Crosse *Republican and Leader* Aug. 28. [9] Portage. In Beloit *Free Press* Aug. 21. [10] Prairie du Chien *Courier* Sept. 21. [11] Merrillan *Leader* Aug. 20. [12] Chippewa Falls *Herald* Aug. 20. [13] Grantsburg *Sentinel* Aug. 27. [14] Elkhorn *Independent* Aug. 19. [15] Mineral Point *Tribune* Aug. 19, 26. [16] Prairie du Sac *News* Aug. 20. [17] Viroqua *Censor* Aug. 18. [18] Menomonie *News* Aug. 28. [19] Prescott *Plaindealer* Sept. 3.

### 1887

This year was a low. Most of the best hunting localities complained of scarcity.[1] In the town of Wheaton, Chippewa County, prairie chickens were "not as plentiful as in former years," while the number of hunters had doubled.[2] The verdict from Elkhorn[3] was that the prairie chicken is "gone."

At Madison,[4] four men on September 1 secured 23 birds in the town of Westport. The only reports of good shooting came from Eau Claire[5] and Chetek.[6] Three Eau Claire hunters are stated to have killed 114 birds in one day.[7] The report of 80 birds taken at West Prairie[8] gives no indication of abundance in the absence of data on time and the number of hunters.

[1] Black River Falls *Independent* Sept. 7; Grantsburg *Sentinel* Sept. 16; Durand *Courier* Sept. 9: Alma *Journal* Sept. 15; Sparta *Herald* Aug. 30; *Democrat* Sept. 10; Menomonie *News* Sept. 10, 17; New Richmond *Republican* Sept. 7, Oct. 12. [2] Chippewa Falls *Herald* Sept. 9. [3] Elkhorn *Independent* Sept. 8. [4] Madison *Democrat* Sept. 2. [5] Eau Claire (w) *Free Press* Sept. 1. [6] Chetek. Barron *Shield* Aug. 26. [7] Eau Claire. In Madison *Democrat* Sept. 8. [8] La Crosse *Republican and Leader* Sept. 17.

### 1888

The gradual elimination of the natural habitat of the prairie chicken, coupled with a low in the cycle, is reflected in the annual decline in the number of references to the species. This year most of the reports again show scarcity.[1] There were statements that a large number of birds had perished during the preceding winter through the formation of a crust over the deep snow in which they had taken shelter.[2]

Fairly good shooting was reported from Necedah[3] and Mauston.[4] It is of interest that on September 1 a hunter killed 21 birds near Racine.[5] Five men hunted a day at Oxford and secured only 12 prairie chickens.[6]

[1] Darlington *Republican* Sept. 21; Kilbourn *Mirror-Gazette* Sept. 8; Portage *Register* Sept. 8; Friendship *Press* Sept. 22; Wautoma *Argus* Sept. 14; Weyauwega *Chronicle* Sept. 5; Chippewa Falls *Herald* Aug. 24, Sept. 7; New Richmond *Republican* Aug. 22, Sept. 5; (Tainter), Menomonie *News* Sept. 7; Barron *Independent* Sept. 13 and (Chetek) Barron *Shield* Sept. 14. [2] Friendship *Press* Jan. 21; Eau Claire (w) *Free Press* Feb. 16. [3] Necedah *Republican* Sept. 7. [4] Mauston *Sun* Sept. 6. [5] Racine *Times* Sept. 3. [6] Portage *Advertiser* Sept. 5.

## 1889

This year the season opened on August 1 and there were complaints of the smallness of the young birds. They were again scarce in nearly all localities.[1]

At Beloit,[2] two men shot 20 birds on the opening day but this bag is exceptional. A hunter at Delavan[3] secured 6 on the opening day while a party of three men with "fine hunting dogs" secured but one. At Grantsburg,[4] two men shot 31, and at Black River Falls[5] one man shot 19 birds in one day. Experienced hunters, during the first days of the season averaged "eight to ten birds" at Chippewa Falls.[6] Three men shot 71 in the town of Bloomer in two days. Good shooting was reported at Poynette[7] and Kilbourn.[8]

[1] Clinton *Herald* Aug. 7; Chippewa Falls *Times* Aug. 7; (Oak Grove). Black River Falls *Journal* Aug. 15; New Richmond *Republican* Aug. 28; Menomonie. *Am. Field* 32 (Sept. 7, 1889) 220; Merrillan *Leader* Aug. 16; Eau Claire (w) *Leader* Aug. 4, 25. [2] Beloit *Free Press* Aug. 3. [3] Delavan *Republican* Aug. 7. [4] Grantsburg *Sentinel* Aug. 16. [5] (Pleasant View). Black River Falls *Banner* Sept. 12. [6] Chippewa Falls *Herald* Aug. 9. [7] Poynette *Press* Aug. 3. [8] Kilbourn *Mirror-Gazette* Aug. 24.

## 1890

Prairie chickens were scarce to "extremely scarce."[1] Four Wausau[2] hunters shot 40 at Grand (Wisconsin) Rapids. At Grantsburg,[3] two men killed 16 birds in two hours, and at Merrillan,[4] two hunters secured 15 in an afternoon. They were considered quite plentiful at La Crosse[5] where two men shot 27 in one half of a day. One hunter shot 40 in unspecified time. The birds were reported plentiful near Dallas, Barron County, where four men took 55 in two days.[6] The hunting of prairie chickens at Superior[7] is again mentioned. A large flock survived the hunting season in St. Croix County.[8]

[1] *Shooting and Fishing* 8, No. 23 (Oct. 2, 1890) 5; Beloit *Free Press* Aug. 8; Waupun. *Am. Field* 34 (Aug. 23, 1890) 173; Montello *Express* Aug. 23; Mineral Point *Tribune* Aug. 7; Friendship *Press* Aug. 16; Kilbourn *Mirror-Gazette* Aug. 16; Sparta *Herald* Aug. 5; Viroqua *Censor* Aug. 13; Chippewa Falls *Journal* Aug. 14; Grantsburg *Sentinel* Aug. 8. [2] Wausau *Pilot and Review* Aug. 19. [3] Grantsburg *Sentinel* Aug. 8. [4] Merrillan *Leader* Aug. 8; [5] La Crosse (w) *Republican and Leader* Aug. 30. [6] Chippewa Falls *Herald* Aug. 8. [7] (White Birch). Superior *Times* Oct. 4. [8] New Richmond *Republican* Nov. 5.

### 1891-1894

During these years prairie chickens increased slowly.

### 1895

This year there was a decided increase in the number of prairie chickens. Near New Lisbon,[1] three men killed 31 on the opening day. At Mauston[2] two men secured 23, and one man 33, in one day. On the opening day, 175 birds were brought into Tomah.[3] While not all of the hunters at Eau Claire[4] had good success, most of the reports were very favorable.[5] The scores showed an average daily bag of 8.6 birds per man. They "never were" so plentiful at Merrillan.[6] Hunters commonly secured 20 to 30 birds daily. At New Richmond,[7] there was "wholesale slaughter." Grantsburg[8] had excellent shooting. Four men during the fore part of the week shot 151 on the marshes at Crooked Lake. Two hunters at Orange killed 70 during the season. Some were killed in a locality near Viroqua[9] where they had been rare of late years. At Mondovi[10] three men took 40 birds in one day. Only a few were shot at Trempealeau.[11]

[1] (Sprague). New Lisbon *Times* Sept. 4. [2] Mauston *Star* Aug. 22, 29, Sept. 5. [3] Tomah *Journal* Aug. 24. [4] Eau Claire *Free Press* Aug. 22. [5] Eau Claire *Telegram* Aug. 4, 20, 22, 24, 31, Sept. 10, 17. [6] Merrillan *Leader* Aug. 9, Sept. 13. [7] New Richmond *Republican* Aug. 29. [8] Grantsburg *Sentinel* Aug. 29; *Journal* Aug. 30, Oct. 11. [9] Viroqua *Censor* Sept. 18. [10] Mondovi *Herald* Aug. 30. [11] Trempealeau *Herald* Aug. 23, 30.

### 1896

The population reached a peak this year. Hough[1] stated: "In Wisconsin also there are more prairie chickens than is known by the average shooter of this section." It was estimated that 1000 birds were killed at Babcock.[2] Eau Claire[3] took the lead in optimism with an estimate of 10,000 birds in the vicinity. There was good shooting at Tomah,[4] Durand,[5] Merrillan,[6] and Grantsburg;[7] also at Mauston[8] where the average bag was 5.7 birds on the opening day, August 20. "Lots of grouse" were reported to have arrived in the vicinity of Cable within the past three years.[9]

There was poor shooting at Sparta,[10] Trempealeau,[11] New Richmond,[12] Prescott,[13] and River Falls.[14]

[1] E. Hough, *Forest and Stream* 47 (Aug. 29, 1896) 166. [2] (Babcock). Tomah *Journal* Sept. 19. [3] Eau Claire *Free Press* Aug. 27; *Telegram* Aug. 22. [4] Tomah *Journal* Aug. 22. [5] Durand *Courier* Aug. 28. [6] Merrillan *Leader* Aug. 14, 28, Sept. 18. [7] Grantsburg *Sentinel* Aug. 27, Sept. 10. [8] Mauston *Star* Aug. 27; *Chronicle* Aug. 13, 27. [9] J. S. I. *Forest and Stream* 47 (Dec. 12, 1896) 469. [10] Sparta *Herald* Aug. 18. [11] Trempealeau *Herald* Aug. 28. [12] New Richmond *Republican* Aug. 27. [13] Prescott *Tribune* Aug. 28 [14] River Falls *Journal* Aug. 27.

### 1897

There was a decided decrease in the population in most localities. Prairie chickens were not nearly as numerous at Necedah[1] as was anticipated. Two men from Manitowoc, on a hunting trip at Necedah, secured 38 birds. This was stated to have been "better" than the bags reported by others.[2] According to Hough,[3] all of the 100 hunters who were at Grand Rapids on the opening day reported poor shooting. There was "fair" shooting at Hancock. At Durand,[4] Viroqua,[5] Trempealeau[6] Grantsburg,[7] and Tomah[8] the birds were few. They were reported scarce also at Oshkosh[9] where the bags ranged from zero to 40 for a party of three men. Four men shot 17 on the same area that yielded 42 the year previous.

The only localities reporting prairie chickens plentiful were Black River Falls,[10] Merrillan, [11] and Chippewa Falls.[12]

[1] Necedah *Republican* Sept. 3. [2] Manitowoc *Pilot* Sept. 9. [3] E. Hough, *Forest and Stream* 49 (Sept. 25, 1897) 247. [4] Durand *Wedge* Sept. 2. [5] Viroqua *Censor* Sept. 8. [6] Trempealeau *Herald* Aug. 13. [7] (Webster). Grantsburg *Journal* Oct. 1. [8] (Adrian). Tomah *Journal* Sept. 18. [9] Oshkosh (d) *Northwestern* Sept. 2. [10] Black River Falls *Banner* Sept. 2, 23. [11] Merrillan *Leader* July 30, Sept. 10. [12] Chippewa Falls *Herald* Sept. 3.

### 1898-1900

During this period the population remained at a low level and it is unnecessary to go into details.

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2 Coues, E. Birds of the Northwest. Washington (1874) p. 410.

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[12] BARRY, A. C. *Proc. Boston Soc. Nat. Hist.* 5 (1854) 9.

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[16] BUNNELL, L. H. Winona and its Environs. Winona, (1897) pp. 237, 238 and 335.

[17] GRIGNON, ANTOINE. *Proc. Wis. Hist. Soc.* for 1913 (1914) p. 123.

[18] La Crosse *National Democrat* Oct. 13, 1857.

[19] La Crosse *Union.* From Milwaukee (d) *Wisconsin* Dec. 24, 1859.

[20] La Crosse (tri-w) *Democrat* Aug. 14 and Oct. 11, 1861.

[21] Prescott *Transcript* April 12 and Aug. 15, 1856.

[22] Hudson *North Star* Aug. 22, 1855.

[23] CARTWRIGHT, DAVID. Natural History of Western Wild Animals. Toledo, (1875) p. 240.

[24] HOYT, J. W. *Trans. Wis. Agr. Soc.* 6 (1861).

[24a] BIDDLE, J. W. Recollections of Green Bay in 1816-17. *Wis. Hist. Soc. Coll.* 1 (1855) 63.

[25] KEMPER, J. Journal. *Wis. Hist. Soc. Coll.* 14 (1898) 436.

[26] WHITTLESEY, COL. CHARLES. *Ibid.* 1 (1855) 73 and 76.

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# CONSERVING ENDANGERED WILDLIFE SPECIES*

HARTLEY H. T. JACKSON

Most of us are familiar with some such expression as "gone like the dodo," "as extinct as the dodo," or "as scarce as the dodo." The dodo was a huge, grotesque, aberrant member of the pigeon tribe, reported to have first been discovered in 1497 by Vasco da Gama on the island of Mauritius. During many years it carried the appropriate scientific name *Didus ineptus*, for of all birds it was inept to meet the competition with humans that was to confront it. About the size of a swan, ungainly, pot-bellied, wings so aborted that it lost the power of flight, ground-nesting and laying only a single egg, and unsuspicious to the point of stupidity, it fell an easy prey to the crews of Dutch ships that visited Mauritius during the first quarter of the seventeenth century and to the Dutch who settled the island in 1644. By 1693 the dodo was extinct. Likewise, a closely related bird species, the solitaire of Rodriguez Island, became extinct about the middle of the eighteenth century. These are striking examples of what has happened to many species in the history of the world fauna, sometimes, as in these cases, with known cause, but more often with cause unknown. It is a regrettable event to have to record the passing of any wildlife race, even though the form may be of only esthetic or educational value. Once a type becomes extinct, it never reappears. It behooves us to care for what we have.

## POSSIBLE CAUSES OF WILDLIFE REDUCTION AND EXTINCTION

Many factors have probably been involved in the extinction of animals. In the geologic past before the advent of man we might theorize on the causes of such extinctions not the result

* Based on a lecture delivered on January 15, 1941, to the class in wildlife conservation of the Graduate School of the United States Department of Agriculture.

of man. Since man's appearance on the scene in recent times, with one or two possible exceptions all cases of wildlife extinction can be lodged in his own hands. Causes other than from man's behavior may have resulted in heavy local losses in wildlife, or often perhaps widespread, but such have rarely endangered the existence of the species. It is difficult in most cases to determine the cause or causes of an extinction. Often it appears that it may be one chief factor, or again it may be several. Extinction in every case was probably brought about at first by gradual depletion of the population and through local extirpation. When the population becomes reduced to a danger point, extinction may come with unexpected rapidity. Dislike the assertion as we may, in recent times the human species has been the prime factor in the extermination of other species.

*Man.*—Man has aided in faunal destruction by the injudicious commercialized use of wildlife. In order to realize this we have only to look back on the days of market hunting when barrels of wild ducks, shorebirds, and pigeons regularly were sold for little or nothing at market, and thousands of big game animals were killed only for selling the hides as a cheap source of leather. The plume hunters went by the board just in time to save the snowy heron and reddish egret, which they had all but exterminated. The whaling and sealing industries operated for many years without restriction.

Hunting and trapping, although for the most part now well under regulation, have taken heavy toll of certain species. Poaching, illegal hunting, and lack of protective laws still menace certain forms of game animals, and some of our more important fur animals have lacked sufficient protection. The apparently inborn urge on the part of some outdoors men to shoot every conspicuous and large living form of wildlife is a serious situation for rare species and one that can be controlled only by conservation education. Extension and improvement of travel facilities in more recent years have increased pressure on wildlife.

Drainage, cultivation, stock raising, and other necessary artificial changes of wildlife habitat have endangered many species. Most of these environmental changes could not have been avoided, yet often wildlife received no consideration when it should have been given a place in the picture.

The introduction of exotic species has often proven to be detrimental to native forms, through either predation or competition. It need be mentioned here only such instances as the introduction of the mongoose, a predator, into the West Indies and Hawaii, and game animals such as the rabbit into Australia, the American gray squirrel into England, the red deer into New Zealand, and the non-game bird, the European starling, into the United States—where it competes for nesting sites with hole-nesting birds, such as the crested flycatcher and the bluebird.

*Natural environmental and ecological changes.*—Most of the natural environmental changes that adversely affected species so as to enhance their extirpation probably were climatic. Some of the major of these climatic changes resulted in the glacial periods, or at least were associated with glaciers, the general effects of which on the flora and fauna are known to most students of biology. Glaciers were the cause of breaking up the geographic range of a species into discontinuous distribution areas, sometimes so small as to endanger the existence of the species. Changes of climate associated with glaciation so affected the remnant population of many species as to be their death knell, and in the late Pleistocene glacial deposits are found the remains of many of these species, and even genera, existing then for the last time. Glacial lake transformation, from fresh-water lake to acid lake, to sphagnum bog, and spruce woodland, completely changed environmental conditions, often to the elimination of some species. Other ecological transformations changed the environment and with it the wildlife population. Volcanic eruptions might well have completely annihilated local forms of wildlife, as for example in the blowing off of the top of Volcan Santa Maria, Guatemala, in 1903, and in the Mount Katmai, Alaska, eruption in 1912. The eruption of Mount Pelee, Isle of Martinique, Lesser Antilles, in 1902, quite possibly exterminated the Martinique solitaire, an interestng and unique songbird.

*Weather.*—Weather conditions, aside from those changes permanently effected by change of climate, may have adverse effects on wildlife. Severe windstorms may, by creating clearings in the forest, actually improve local environment for some wildlife species, yet a storm of the same intensity on a marsh or a sandy area might destroy much of the wildlife. It is probable that the Cape Sable seaside sparrow, found only on the salt marshes of southwestern Florida, was wiped out of existence by the Florida tornado of 1937. The possible effects of drought on wildlife are fresh in our minds from conditions created by drought in waterfowl nesting areas of the Northwest less than a decade ago. Cold or wet seasons, especially during a breeding season, may often reduce populations, and sometimes to a danger point.

*Struggle for existence.*—The "struggle for existence" is an old evolutionary term, more or less hackneyed; nevertheless, overspecialization may place a species at a disadvantage in competition with forms less specialized and better able to meet competition and changed environment. Gigantism, a type of specialization, may of itself have been a factor in the disappearace of many of the gigantic reptiles and mammals of past ages.

*Disease.*—Evidence clearly indicates that diseases have at times been important factors in reduction of populations of wildlife. Diseases and parasites, however, disseminate more freely in dense populations, so that the effect is to produce population fluctuations, or cycles. Beyond this initial reduction of such populations, disease is probably not as a rule an important factor in the extermination of a species.

## Wildlife Species That Have Become Extinct

Although our own country in the past has abused its wildlife population to the extent of exterminating several species, and has been negligent in many ways in preserving vanishing forms, it has not been alone in this. Before considering extinct North American animals, let us glance at the headstones of the graves of some of the foreign species. No pretense is made here to compile a complete list of extinct animals of foreign countries, and only some of the more noteworthy or conspicuous are included.

In Europe, such an important mammal as the aurochs, ancestral stock of some of our domestic cattle, which inhabited large areas of central and southern Europe, and also northern Africa, passed into the vanished species in Poland in 1627. A few years later the tarpan, an ancestor of the domestic horse found on the steppes of southeastern Russia, became extinct, although a close relative, Przewalsky's or the Mongolian, wild horse, still exists in small numbers in Mongolia.

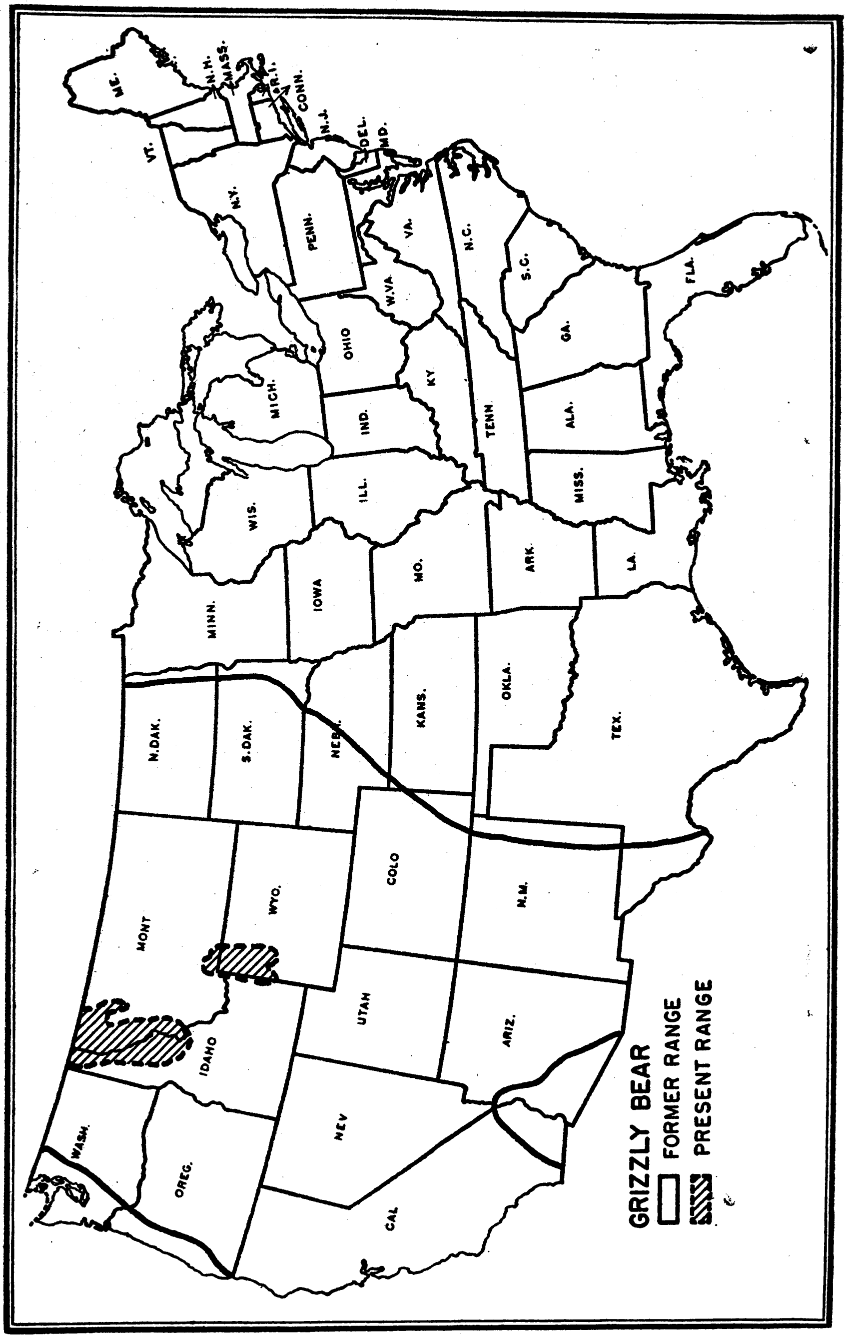
In Asia, Pere David's deer that formerly inhabited parts of North China is extinct in the wild state, and even in its native country. At the time of the Boxer Rebellion in 1900, some 200 animals, all that remained in China of this species, held in captivity in a park near Peking, were killed for food. Fortunately, a few animals had previously been sent to England by the Duke of Bedford, where about 50 are now maintained at Woburn. Steller's sea-cow, a huge manatee 30 or more feet long and weighing upwards of 3 tons, first brought to the attention of science in 1741, met its doom in 1768 in supplying oil and food for man. This huge manatee inhabited Copper and Bering Islands and possibly other islands in Bering Sea. The Pallas cormorant, an interesting fish-eating bird of the Commander and other Bering Sea islands, became extinct in 1852.

Among wildlife species that have been exterminated in Africa, the first to go by the acts of modern man was the blue antelope, or blaaubok, which disappeared in 1799 from South Africa. From South Africa also disappeared about 1875, through hunting, the quagga, which resembled a donkey with zebra-like stripes on its cape and neck only. Burchell's zebra became extinct in South Africa some 25 years later. In northern Africa, in the mountains of the Algerian Sahara, the red gazelle has probably vanished for all time.

Turning now to Australia and the South Sea Islands, those giant flightless birds, the moas, disappeared from the feathered fauna of New Zealand islands, probably between 950 and 1350 A. D. Undoubtedly the last remnants vanished through the agency of man, although ancient Maori tradition and legends refer to the moa as burnt up by the "fires of Tamaten" in times long past, which may refer to its destruction by volcanic action. Archey (1941) recognizes 19 species of these birds belonging to six genera. In Australia itself the little plains rat-kangaroo has not been seen since 1843, and the marsupial anteater vanished in 1923.

Many forms of wildlife have become extinct in the Western Hemisphere. Some of the earlier of these to vanish were insular forms, such as Gosse's macaw from Jamaica, about 1800. The Cuban tri-colored macaw, chiefly through utilization for food, became extinct in 1864. The history of Guadeloupe Island, one of the Leeward Islands, portrays the extinction of three bird species, the yellow-winged green parrot, the purple Guadeloupe parakeet, and the Guadeloupe macaw. Strangely enough, an island of like name in the eastern Pacific Ocean, Guadalupe Island, has witnessed the extirpation of the Guadalupe caracara and probably the Guadalupe towhee and the Guadalupe rock wren.

Several races of mammals formerly inhabiting North America —in fact, in parts of the United States—have passed in the procession of the vanished. The big dark buffalo of the northeastern United States, the Pennsylvania bison, was last known in Pennsylvania in 1801. The Maine giant mink, nearly twice the size of our ordinary minks, that lived along the seacoasts of Maine and Nova Scotia, became extinct in 1860. The eastern puma, or cougar, was gone by about 1885. Of our grizzly bears, the first to disappear was the Texas race (1890), followed shortly by the Plains grizzly (1895), and the Tejon grizzly of the arid southwestern region of California (1898). Although the taxonomic status of the grizzly bears is not entirely clear to our satisfaction, it is, nevertheless, certain that many races of these mammals are recognizable and that many of these have disappeared. Among these extirpated forms may be mentioned the California grizzly bear (1922), Sacramento Valley grizzly, California coast grizzly, Arizona grizzly, Black Hills grizzly, Navaho grizzly, Mount Taylor grizzly, Utah grizzly, and Chelan grizzly. Even such an insignificant mammal as the Gull Island meadow mouse could not escape extinction when its habitat on Great Gull Island, at the entrance of Long Island Sound, New York, was covered by earth moved in grading the island for fortifications sometime before 1898. Another inconspicuous small mammal, the Amargosa meadow mouse, known only from a small tule marsh at a spring near Shoshone, eastern Inyo County, California, had vanished by 1916 after the marsh had been burned several times and been used for a pasture. The largest of our elks, the Merriam elk of Arizona and New Mexico, was extermin-




MAP 1. Former range and present range of grizzly bears in United States.

ated by 1900 or before. The Audubon or Badlands bighorn sheep of the Dakotas and eastern Montana was last known alive about 1914, and it is quite probable that the lava beds or rimrock bighorn of southeastern Oregon and northwestern Nevada has gone. No longer will any stockmen need to worry over depredations of the big plains wolf, which ceased to exist about 1930.

Within the borders of the United States, five forms of birds are now certainly extinct, namely, the great auk (1844); the Labrador duck (1875); the passenger pigeon (last native wild bird, 1908, last survivor in captivity, died of old age in the Cincinnati Zoological Gardens, September 1914); the heath hen, or eastern representative of the prairie chicken, was last seen alive on March 11, 1932, and can be said to be extinct in 1933; and the Carolina paroquet about 1935, or previous thereto. Two other species are probably gone, the Eskimo curlew, of which there have been only very indefinite and unsatisfactory records for recent years, and the Cape Sable seaside sparrow, probably wiped out of existence by the tropical hurricane of southern Florida in 1937.

## Endangered Wildlife Species

We shall not go into details as to the status of all foreign vanishing and endangered wildlife, but we should know at least a few of the species that are in a more precarious condition in continents other than our own. Europe, through private and public game preserves, has been able to care for most of its wildlife species. The eagle owl has been persecuted and is in some danger, and the white stork, though at least up to the time of the present war well protected in Europe, where it nests, has been depleted in numbers through being killed for food by natives in its African winter home. The European brown bear is becoming exceedingly rare, and the ibex and chamois are in danger, as is also the European beaver. The visent, or European bison, became so reduced in numbers that resort has been made to crossing it with the American bison and domestic cattle of old-lineage strain in order to retain some semblance of the species. Even these may now be wiped out through economic strain of wartime conditions.

We have already mentioned the status of Przewalsky's horse in Asia, but in that continent the ancestor of the donkey, the kiang, is so reduced in numbers as to be nearing the danger line. Other Asian mammals in danger of extirpation include the seladang, a huge wild ox of India; that large deer, the Malayan sambhur; and the three species of Indian rhinoceroses—the Asiatic two-horned, the Indian one-horned, and the lesser one-horned. The last named has most likely already vanished. Many of the species of pheasants especially need attention if they are to be saved, and the Argus pheasant is actually endangered.

Africa, long known as the continent of many species of remarkable antelopes and other big game animals, has maintained, particularly through the British and Belgian governments, extensive game preserves, and as a rule offered protection to wildlife. In spite of this effort to save the fauna, however, a few species have become extinct and several others are vanishing. No less than a dozen species of antelopes are endangered, among which is the beautiful inyala, now probably limited to about 200 individuals in Kruger Park. The Bubal hartebeest of North Africa has become scarce, and the Cape hartebeest reduced to about 40 animals. In the case of the bontebok of South Africa, 23 were driven in 1929 into an enclosure of 1800 acres set up as Bontebok National Park. Of these animals, 16 survived and some increase maintained half-domesticated. There are not over 60 bonteboks alive today. The blesbok, a closely related antelope, is in about the same status as the bontebok. Other African antelopes in danger of extirpation include the white-tailed gnu, the giant sable antelope, the giant or Lord Darby's eland, the gemsbok, and the addax. The rare and unique okapi, modified forest giraffe of the Congo forests, is decreasing in numbers. Other mammals in serious danger in Africa include the Abyssinian ibex, mountain zebra, white rhinoceros, hippopotamus, South African elephant, and gorilla. Among several African birds endangered is the unique shoebill stork.

Australia, the land of marsupials and many strange animals, is on the verge of losing more of its unique species. Special legislation prohibiting the taking of certain fur animals and forbidding even the exportation of the fur or any part of the animal may save some of these species. Especially in danger is the koala, often nicknamed the "teddy bear," and the gray wallaby, one of the larger kangaroos. The estimated population of koalas in Australia decreased from 250,000 to 1,100 in a few years before the establishment of a preserve for the species on Phillip Island, Victoria, about 1938. In February 1942 there were 590 koalas in this colony. The hairy-nosed wombat and the Tasmanian wolf, or thalacine, are both nearing extermination. It is doubtful if the beautiful lyre-bird can be saved. The hawk parrot, as well as several other parrot species, are on the way to oblivion.

In South America protection may have come too late to save in its native habitat the now rare fur-bearer, the chinchilla, as well as the guanaco, wild ancestor of the domesticated llama, and the vicuna, native wild ancestor of the domesticated alpaca. Three species of the ostrich-like bird, the rhea, are near the vanishing status in South America, as are the bell bird, and the steamer ducks, flightless ducks of Tierra del Fuego.

North America, where our interests more naturally center, has a long list of endangered wildlife races, at least 50 in number, of which all except one or two marine forms occur in the United States or its territories. Several of the grizzly bears have already gone, and within the states it would seem that Yellowstone National Park and Glacier National Park offer about the only real hope for their preservation. Black bears as a group are reasonably safe, yet the Florida black bear is reduced to less than 500 and is decreasing in population. That frosty-gray bear of the black bear group, the glacier bear of Alaska glaciers, is so scarce as to face extinction. Its remote and almost inaccessible habitat may save it.

The fisher, the marten, and the wolverine have all been reduced so much by their being trapped for fur that they are almost gone from the United States and reduced to the danger point everywhere in North America. The black-footed ferret, formerly found on the plains with a geographic range almost coinciding with that of the prairie dog, was never a common mammal, but has become rarer and rarer, until now it is seldom reported. The southern sea otter was a few years ago believed extinct, when unexpectedly a small herd was discovered south of Carmel, Monterey County, on the coast of California. This herd now numbers about 300 animals or more, though recently tending to become scattered. It is protected and guarded carefully, which may with proper management suffice to save the race from extinction.

The unsuspecting little kit fox of our western plains was not only easily trapped for its fur but also frequently was caught in traps set for coyotes and other animals. No restrictions seem to have been placed on killing it, with the result that what was once a common mammal is now rare, and in many regions extirpated. The timber wolf of the northeastern states could hardly be expected to withstand settlements and civilization and has almost succumbed to the inevitable. In fact, all the large wolves of the United States are endangered. The eastern puma, or cougar, has been exterminated. Among the other cougars, the Florida subspecies is the most endangered, there being probably less than 25 individuals left.

Several of our seals are reduced to the point where we should take serious concern for them. The Guadalupe fur seal of the west coast of Mexico has reached too low a population for its safety, and may have even vanished, and both the West Indian monk seal and the Pacific monk seal have become rare and reduced to local habitats. That oddity of seals, the elephant seal of the Pacific Coast, has shown some recovery during the past decade, but is still in a precarious condition. On the North Atlantic coast, the beautiful hooded seal has been hunted for oil and fur until it, too, is in danger. The Pacific walrus, while in some danger, is not reduced to the vanishing stage, as appears to be the case with the Atlantic walrus.

We correctly think of the white-tailed deer as our most abundant big-game animal, yet the Pacific white-tail is down to about 1000 animals, and was supposed to have a much lower population until Dr. Victor B. Scheffer (1940) gave an account of a herd at the mouth of the Columbia River. The key deer, inhabiting a few of the lower Florida keys, is very rare, local in distribution, and probably does not number more than 40 individuals. It was reduced by the hurricane of 1937, and has been over-hunted and subjected to poaching until only a few remain.

When the mad rush for gold was on in California during the middle of the nineteenth century, the great valley of California, the combined valleys of the San Joaquin and the Sacramento

Rivers, abounded in a small elk with simple antlers, the California valley or tule elk. It soon became scarce. A remnant was protected on the Miller and Lux Ranch, Buttonwillow, Kern County, California. In an effort to save these animals, which may have reached a total of 350 or 400 animals in 1921, some were transplanted in Yosemite and Sequoia National Parks. In 1933 all of these, and several from the Buttonwillow herd, were transferred to a reservation with good elk-pasture features in Owens Valley. Today there probably exist alive not over 150 of these elks, nearly all in Owens Valley, though a few may still survive on the Buttonwillow Ranch.

The last woodland caribous seen in Maine were near Mount Katahdin in 1908. They had disappeared from New Hampshire and Vermont about the middle of the nineteenth century. Fifteen occur in northern Minnesota, only two of which are native, the others being from stock brought in from Saskatchewan. In Canada also the woodland caribou is vanishing, and in many regions where it was once common it is now gone. The eastern moose, while not in so much immediate danger as the woodland caribou, is nevertheless rapidly approaching a precarious situation.

All of our bighorn sheep should give us cause for worry. Two forms are in especial danger. The Sierra bighorn may be reduced to less than 75 animals, and the Texas bighorn, at one time thought to be extirpated, is reduced to some 125 animals scattered in 6 or 8 mountain ranges and engaged in an almost hopeless fight through competition with domestic sheep and goats, and illegal hunting, unless reservation provisions are offered it. The desert bighorn, through the establishment of national refuges in Arizona and Nevada for its preservation, has, we hope, been saved.

Unique among all mammals, the odd looking musk-ox, which resembles somewhat a miniature shaggy-haired buffalo and combines certain features of the cattle tribe on the one hand with those of the sheep on the other, is dwindling in numbers. Although formerly occurring in the barren grounds from northern Alaska to eastern Greenland, it is at present found native only on the east coast of Greenland and in Arctic barrens directly north and northwest of Hudson Bay as far as about latitude 83 degrees. Even within these ranges musk-oxen inhabit only certain areas, and there are immense expanses where none occurs. Attempts are being made by the Canadian government to colonize the species in the Dominion. Of an initial stock of 34 musk-oxen brought by the United States Fish and Wildlife Service from Greenland via Norway and the United States to Alaska in 1930, and held at the United States Biological Survey Experiment Station, Fairbanks, for study and acclimatization, 4 animals in 1935 and 27 in 1936 were introduced on Nunivak Island National Wildlife Refuge in Bering Sea. This introduction had in 1941 increased to more than 100 animals.

Stories and legends about mermaids originated in superstitions about those peculiar aquatic mammals, the dugongs and the manatees. In their present distribution, dugongs inhabit only parts of the Eastern Hemisphere, whereas the three species of manatees occur only in the Atlantic coastal waters of America from Florida to Brazil. The manatees are harmless mammals that feed on aquatic vegetation. All may be included in the endangered list, but the most northerly form, the Florida manatee, is in an especially critical status. Ample legal protection, it would seem, is afforded the animal, but laws are not always enforced, and many are wantonly shot. Sudden drops in temperature to freezing, or two or three nights of freezing weather, often kill manatees.

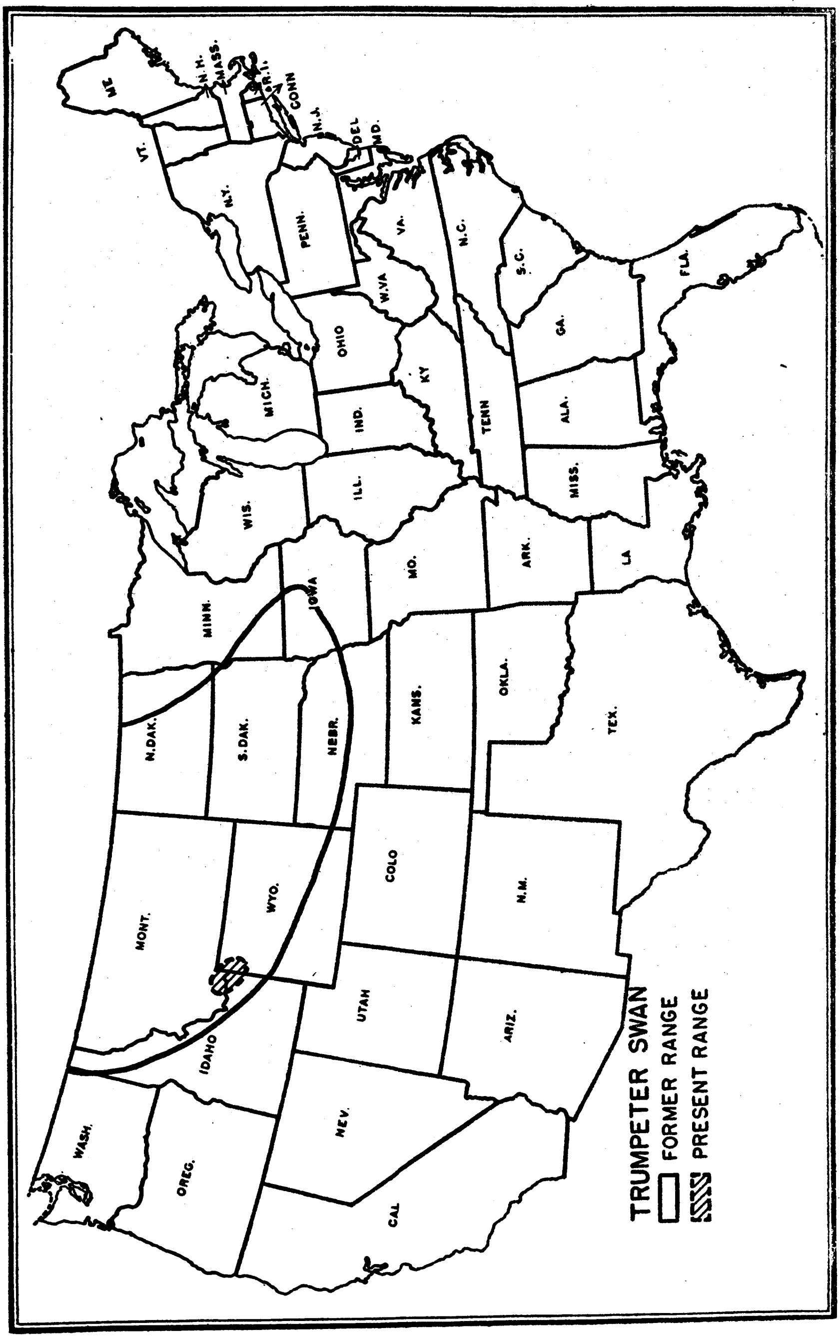
Even some of our smaller game mammals need especial protection if we expect to continue them as a part of our American life. The northeastern fox squirrel and the mangrove fox squirrel are both at such low population as to be near the vanishing point.

With their high value for oil and other commercial products, all the large whales face probable serious reduction in numbers. Three species are now at the danger point. The gray whale, found off shores in the north Pacific and at one time important in the whaling industry, is so reduced in numbers that only a few are procured annually. The bowhead whale, some 50 feet long and with massive, heavy head, formerly occurred throughout the oceans near the North Pole. It became extirpated in the north Atlantic some 50 years ago and is now limited to a sparse population in Bering Sea and towards the northeast thereof.

The North Atlantic right whale, another massive whale that produced a heavy yield of oil and whalebone, was so eagerly sought by whalers in the North Atlantic that it has been reduced almost to extirpation. This species has long ceased to be an item of commercial importance. The Whaling Treaty Act of 1936 should tend towards conservation of whales. Nevertheless, during 1937-1938, there were 54,664 whales killed, a yearly high for all time. Of these, 46,039 were captured in the Antarctic region. What effect World War II will have on whales and the whaling industry is problematic. There is need for whale products in war industries, but there is also demand for the use of ships employed in whaling for other war purposes. Moreover, the risk in whaling during war times may tend to curtail the industry.

There are many North American birds that are in a more or less precarious situation as to their future existence. Some of these, such as Leach's petrel, reddish egret, Franklin's grouse, southern white-tailed ptarmigan, sage hen, golden plover, and upland plover, it would appear are holding their own, or possibly on the uptrend, though once greatly reduced in numbers and hard pressed. Others are in the more precarious class. The great white heron population of extreme southern Florida shows no appreciable increase, although protection is afforded these birds on the Great White Heron Refuge, where about half of all birds dwell. In October 1938 Alexander Sprunt, Jr., counted a total of 585 great white herons; in February 1941 Harold L. Peters counted 551, of which 290 were on the National Great White Heron Refuge. The roseate spoonbill, beautifully colored and grotesque of bill as the name implies, is possibly in more danger as a nester in the United States than the great white heron, though actually at present more birds exist. It is found in the same general region of Florida as the great white heron, but has a supplementary chance for survival in a larger colony in Texas. There are a considerable number of the birds in Mexico. The Florida nesting birds are decreasing in numbers. The Texas nesters have increased, but are in constant danger from possible destruction through oil development.

Another strictly American bird being preserved by refuge management is the trumpeter swan, the largest of American waterfowl. Formerly nesting from northwestern Iowa and cen-




MAP 2. Former breeding range and present breeding range of trumpeter swan in the United States.

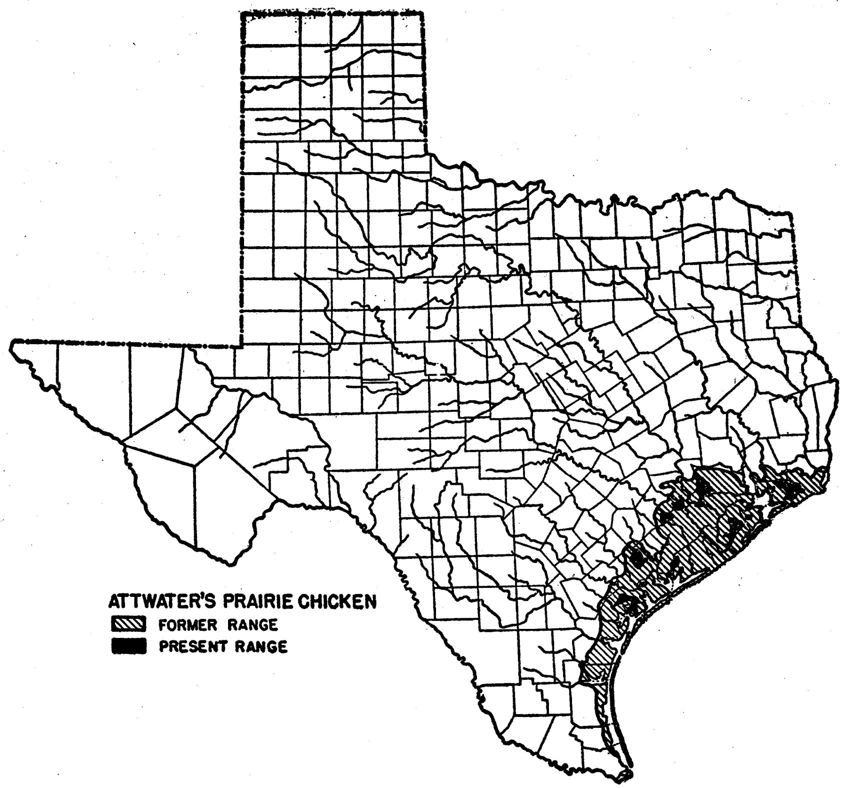
tral Nebraska northwesterly to central British Columbia and Alberta, it is now limited during the breeding season to the vicinity of Yellowstone National Park, Wyoming, and the Red Rock Lakes National Wildlife Refuge, Montana, and to a refuge at an undesignated locality in western Canada. At each of these breeding areas, the birds are being carefully guarded. In the Yellowstone-Red Rock Lakes regions there has been an increase from 33 birds in 1934 to 211 birds in 1941. In Hawaii, the nene, or Hawaiian goose, has faced destruction by man and the mongoose. There may be 100 or more of these dryland geese in captivity, but the species is probably reduced to about 25 individuals in its native wild state. The Laysan teal is another of duck-and-goose tribe confined to Laysan Island southwest of Hawaii. It is at an extremely low ebb, and though inhabiting a national bird refuge, it may pass into history at any time, if it has not already gone. There were only 14 birds left on the island in 1923.

Many of our birds of prey, even though actually beneficial species, have been shot on sight as harmful, or considered legitimate targets on which to test marksmanship. Practically all species of this group have been reduced in numbers. Probably the most seriously endangered is the California condor, masterful airman of graceful flight and grandeur, and man's benefactor as a destroyer of carrion. The California condor formerly ranged west of the Sierra Nevada from Washington to Lower California, and in the days of the "forty-niners" was not rare. It is now reduced to not more than 70 individuals, most of which make their home in a comparatively small isolated valley in a range of mountains in southwestern California. Two other birds of graceful flight and beauty and both of harmless habits, the white-tailed kite of the southwestern United States and the Everglade kite of Florida, are extremely reduced in numbers. The whitetail is probably in less danger than the Everglade, since its present distribution is more extensive and it is known to nest in several scattered colonies. The Everglade kite, however, is known to nest in the United States only in the vicinity of Lake Okeechobee, Florida, where there are only a few pairs of birds.

Three of our gallinaceous birds are approaching the vanishing point. None of the existing races of prairie chickens is in any too satisfactory a status, and one of them, Attwater's prairie chicken, is reduced to approximately 8,000 birds inhabiting scarcly more than 5 percent of the former range of the race. The population of these prairie chickens has been reduced not only by hunting but also by general agricultural and grazing practices, and by excessive rainfall during the nesting season. The masked bobwhite, formerly occurring in fair numbers within the United States near the Mexican border, became extirpated except for local colonies in Sonora, Mexico. From this meager Mexican supply an effort has been made to restock the species in Arizona and New Mexico. The eastern wild turkey, the native wild turkey of our Atlantic coast colonists, has all but disappeared as a pure-strain wild turkey. A few of them still inhabit the region of the lower Santee River in South Carolina, from which, under the auspices of the United States Fish and Wildlife Service, 15 birds were placed on Bull's Island, South Carolina, a national wildlife refuge, in 1939-1940. This stock has increased, and will provide another flock of pure-strain wild birds. Elsewhere there are birds that show characteristics of the original native stock, but a large portion of the population shows crossing with domestic turkeys.

The whooping crane, a white bird nearly man-high, formerly occurred during migration from the Atlantic coast south to Georgia and west to the foot of the Rocky Mountains, was known to nest from Iowa and Nebraska north and northwest to Hudson Bay and Mackenzie, and wintered in huge flocks in the Gulf States. Being big and conspicuous, and an inhabitant of the open places, it afforded "something to shoot at" for the unprincipled gunner who was out only to kill. It was reduced to a low population of possibly not more than 25 individuals by about 1925, and even today there are almost certainly less than 100 living. They no longer nest in the United States, and the wintering flocks sojourn chiefly in Texas. Each winter a few visit the Aransas National Wildlife Refuge in southern Texas, 26 individuals having been observed there during the winter of 1940-1941. The Florida sandhill crane, a grayish bird smaller than the whooping crane, confined to only a few nesting localities in Florida and one in Georgia, is dwindling in numbers and can be saved only by diligent protection.

Several shorebirds are becoming scarce, even though provided protection through the Migratory Bird Treaty Act. The last specimen record of an Eskimo curlew for the United States was in Nebraska in April 1915, though a bird was collected in Argentina in January 1925. One was reported as a sight record from Hastings, Nebraska, April 8, 1926. There are no reliable




MAP 3. Former range and present range of Attwater's prairie chicken in Texas.

records since then, and the species is probably gone. Of other shorebirds, the Hudsonian godwit seems to be nearest the vanishing point. It nests on the "Barren Grounds" from Alaska to Hudson Bay, and migrates to winter in South America. It became greatly reduced during the game-marketing days of the eighties and nineties and has never been able to recover.

The largest and most magnificent woodpecker of the United States, the ivory-billed woodpecker, is now lowered to a few individuals. Probably all of these, and certainly most of them, are in a heavily forested tract in Louisiana. Dense forests of large trees are essential for the existence of the ivorybill. Unless its Louisiana home can be saved from the lumberman's ax, the ivorybill is doomed. And with the urgent war call of "Timber! Timber!" the outlook for retaining this species in our fauna is not hopeful.

Three of our small passerine birds have approached the danger line. One of these, the dusky kinglet, a midget bird of Guadalupe Island, Lower California, may now have followed other vanished birds on that island. Bachman's warbler of the southeastern United States, always in recent times a rare bird, barely maintains its population, and in general appears to be on the decline. The Ipswich sparrow, a species related to the savannah sparrows, has a breeding range restricted to small Sable Island, Nova Scotia, and in winter is found from there south along the sand dunes of the Atlantic coast to Georgia. On Sable Island it nests only near the beach. Wave action from severe storms may at any time destroy its nesting habitat.

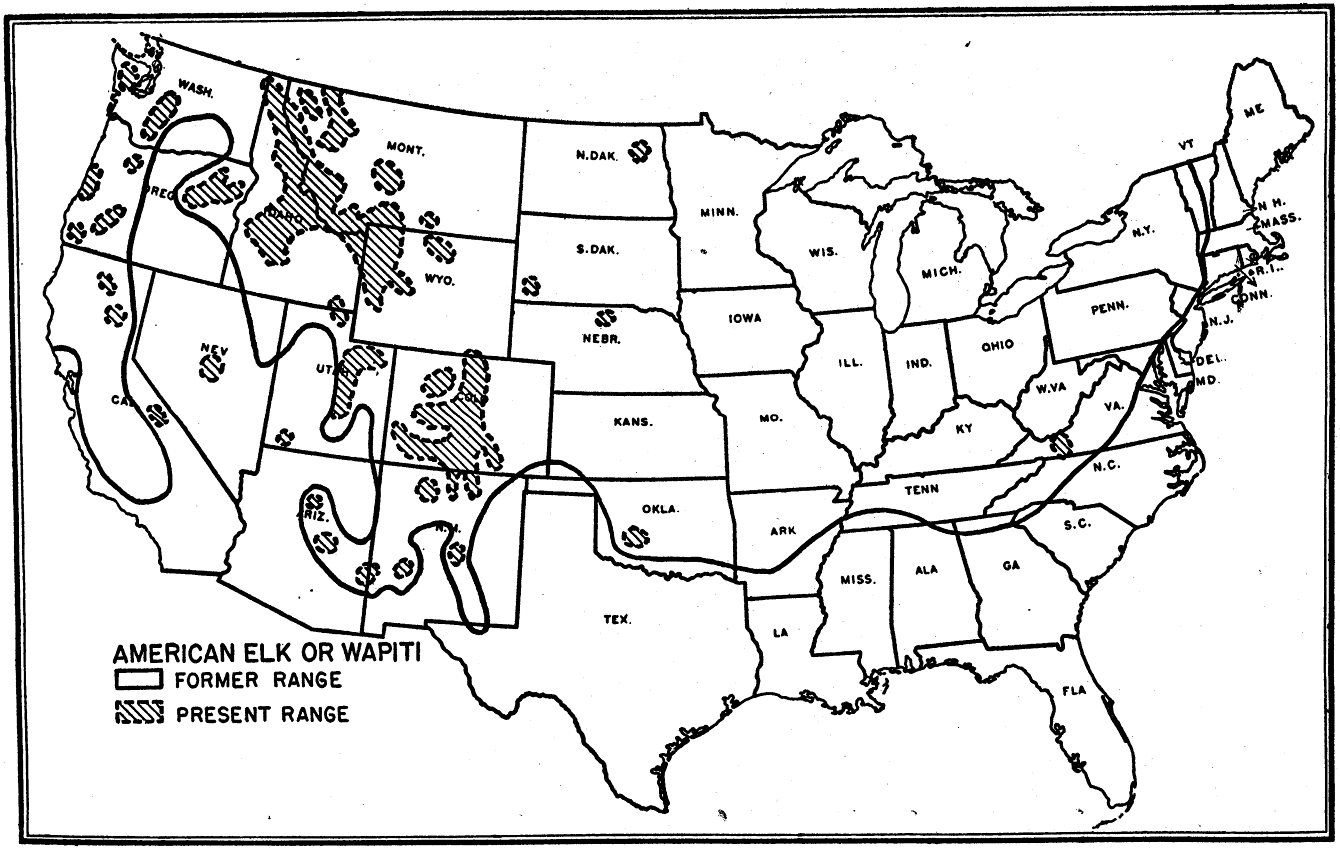
Both the American crocodile and the Mississippi alligator have decreased in numbers in their habitats in the swamps of the southeastern states. The crocodile never occurred within our United States boundaries proper except in extreme southern Florida. It differs from the alligator in its longer and slenderer body, its much more pointed snout, and longer teeth. Both the crocodile and the alligator have been hunted for their hides for use in leather manufacture. Many of them have also been wantonly killed out of sheer prejudice and hatred for an ungainly reptilian with an unfriendly appearance. The catching of the young of both species and commercializing their sale as pets to be transplanted to a more northern climate unsuited to them has killed hundreds. The crocodile is almost a relic of the past in the United States. The alligator, under proper protection, will probably stay with us.

Of our highly edible fishes, two species of sturgeons, the common and the lake, have been so reduced in numbers, largely by commercial fisheries, as not only to have become of little commercial importance but also are in actual danger of extinction. The Lake Superior whitefish, to many of us the grandest of all table fish, finds itself in almost the same status as the sturgeons. And on our eastern coast, the thousands of Atlantic salmon that formerly, early in summer, ascended many of the New England streams to spawn, now migrate only by hundreds in one or two rivers, more notably the Penobscot.

### Some Species That Have Recovered

Dark as the picture is for many of the wildlife forms before mentioned, there is a light of hope for saving some of them if appropriate action is taken. Examples we have of wildlife species that have recovered after being on the verge of extinction offer that illumination. The American bison roamed the prairies and plains of the United States and Canada in herds that in pioneer times certainly aggregated more than 50,000,000 animals. By the close of the nineteenth century, the population had probably reached its low at a total of about 800 animals. The American Bison Society estimated 1,917 living animals in 1908. Shortly afterwards, through the efforts of that Society, the National Bison Range was established under the administration of the Biological Survey on land formerly a part of the Flathead Indian Reservation, Montana. It was stocked October 17, 1909, with 37 bisons, all but one from a private herd at Kalispell, Montana. This was really the beginning of the upbuild of the American bison population. Today there are more than 5,000 bisons in the United States, mostly confined to ranches, parks, and refuges, and another possible 30,000 on refuges in Canada, a total of not less than 35,000. Nineteen bisons from the National Bison Range were introduced into the Big Delta region, near Fairbanks, Alaska, and had in 1941 increased to more than 200 animals. In this region they are given free range. Modern civilization and agricultural practices in most localities in the United States no longer make possible the free-ranging of vast migrating hordes of big-game animals. We can, nevertheless, save a species from extinction as witness the bison.

That peculiarly American mammal, the prong-horned antelope, through protection of refuges and by management and




MAP 4. Former range and present range of the American elk in the United States.

Most of the present range population is from introduction of Rocky Mountain elks, including the areas of Nevada and southwestern Utah outside the original range. The area in eastern California outside the former range boundaries indicates the transplant of tule elks.

hunting control, has increased from a low of about 30,000 in 1920 to 175,000 in 1941. And the American elk, or wapiti, by transplantation of individuals of the Rocky Mountain subspecies, mainly from Yellowstone National Park and the National Elk Refuge in northwestern Wyoming, has been reestablished in many localities where it formerly dwelt. A few bands of elks have even been established in localities outside their ancestral distribution, including herds of Rocky Mountain elks in southwestern Utah and Nevada, and tule elks in eastern California. The combined populations of all forms of elks have increased in the United States from a low of near 20,000 in 1905 to more than 200,000 in 1940.

One of the outstanding examples of saving an animal from extinction and restoring a valuable natural resource is that of the Alaska fur seal. Briefly outlined, the history may begin with a fur seal population of more than 4,000,000 animals in 1867, when the United States purchased Alaska. Commercial exploitation, with its associated pelagic sealing, or taking seals at sea, and its almost unrestricted killing of seals, rapidly reduced the population. By 1911 the population had been reduced to 125,000 seals, less than the annual kill in some previous years. On December 15, 1911, a convention for the preservation and protection of fur seals was entered into force, to which the United States, England, Canada, Japan, and the Union of Soviet Socialist Republics were parties. Pelagic sealing by the nationals of each country was abolished. Management of fur seals on the breeding rookeries was left chiefly to the nation having jurisdiction over the locality. The United States, therefore, had charge of the great seal rookeries on the Pribilof Islands, probably involving more than 85 percent of the breeding stock. Provision was made for each of the nations to turn over to other nations of the convention a percentage of the seal skins taken on its shores. Under this protection, the seal herds increased to about 2,300,000 in 1941, and under managed cropping 800,000 fur seal pelts were harvested in 20 years, from 1921 to 1940. The convention, however, was terminated on October 23, 1941, Japan having withdrawn after one year's notification of her intentions.

There are several species of birds that have made recovery

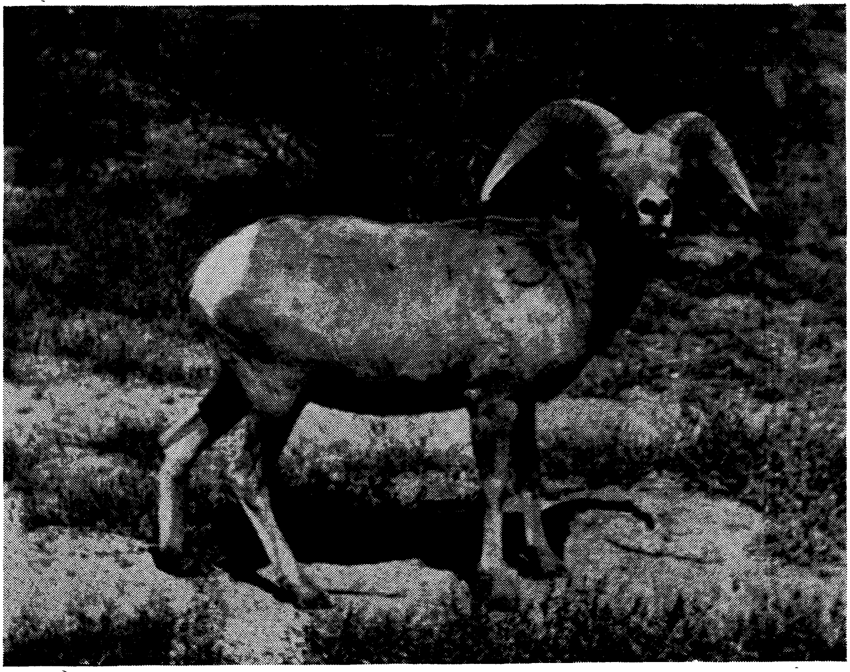


FIG. 1. Desert bighorn, or Nelson's mountain sheep. A middle-aged ram at Boulder Canyon Wildlife Refuge, Nevada.

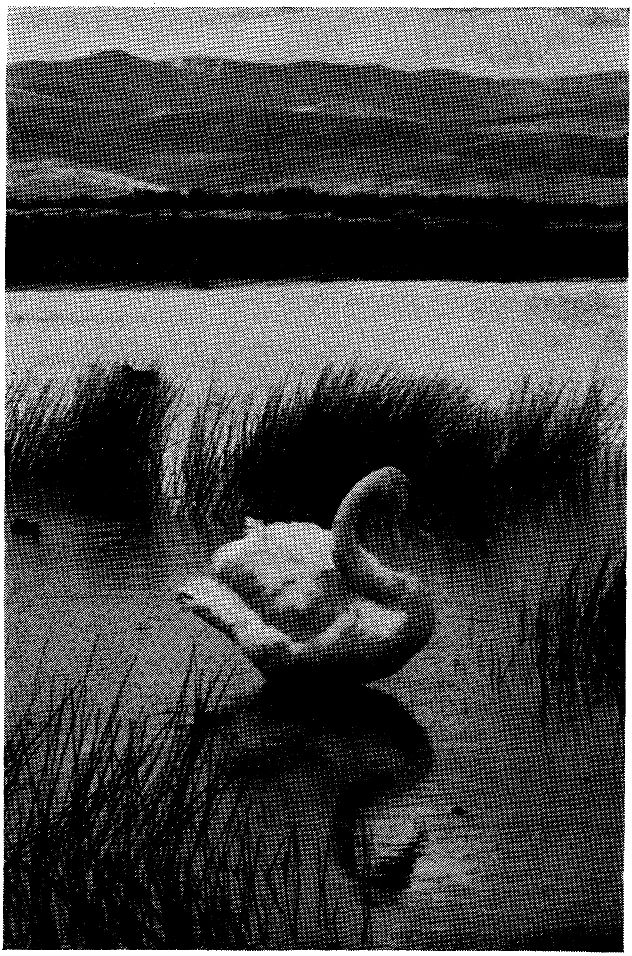


FIG. 2. Trumpeter swan. Red Rock Lakes National Wildlife Refuge, Montana.

after being near the border of death as a species. Possibly among the most notable of these are the American egret and the snowy heron. Both of these species were nearly wiped out by "plume hunters" who sought the adult birds during the breeding season in order to procure feathers for millinery purposes. The American egret, transcontinental over the southern United States, has now become a common bird, and it would seem may have extended its breeding range to the northward beyond its ancestral range. The snowy heron, although not showing the rebound of its sister heron, is nevertheless no longer in serious danger. That most beautiful of all American ducks, the wood duck, has also increased from a low population to one sufficient for insuring with ample protection the continuance of the species.

## Methods of Preserving Species

The most important factor in preserving wildlife species is that we control ourselves until man will no longer be the most destructive animal. Such control is making progress, though often against the inclinations of the man who sees in wildlife only an easy outlet for self-gain without regard to his own future or that of the following generations. General methods of conservation are now well formulated. Possibilities for improvement naturally will present themselves. The essential thing is to act when we know what should be done. Federal, state, and county governments and national and local organizations all have a hand in this work. When a widely distributed species is endangered, however, it becomes a national problem, and as such should be entrusted to our national wildlife agency, the United States Fish and Wildlife Service.

*Adequate organization* is needed to administer funds and work projects, to supervise activities, to enforce legal protective acts, and to manage wildlife and wildlife areas.

*Legal protection,* both federal and state, is a necessity. The many state fish, game, and other wildlife laws are not familiar in detail to most of my readers, but we all know there are many such serving a useful purpose. Among national laws there is the famous Lacey Act (Act of May 25, 1900, 31 Stat. 187—18

U. S. C. 395) regulating interstate commerce in wild birds and other animals. A similar law passed in 1926 applies to interstate transportation of black bass. The bald eagle, our national bird symbol, has been given legal protection (Act of June 8, 1940, 54 Stat. 250). Other federal laws have provided for national wildlife refuges or provided for protecting wild animals and birds and their eggs and government property on federal refuges.

The range of many species of wildlife, particularly during migrations, may cover territory of more than one nation, or species may inhabit international ocean waters. When such is the case and protection is necessary, resort is made to treaties among the nations involved. Agreement is made to a convention between or among the nations covering the essential reasons for acting and the objective and means of accomplishment. An enabling act on the part of each nation is necessary for enforcement action on the part of that nation. Thus Migratory Bird Treaty Act (Act of July 3, 1918, 40 Stat. 755, as amended by Act of June 20, 1936, 49 Stat. 1555—16 U. S. C. 703-711) and the Migratory Bird Conservation Act (Act of February 18, 1929, 45 Stat. 1222, as amended June 15, 1935, 49 Stat. 381—16 U. S. C. 715) are enabling acts a "Convention between the United States and Great Britain for the Protection of Migratory Birds in the United States and Canada," as signed in Washington on August 16, 1916, ratified by both the United States and Great Britain the same year, and proclaimed on December 8, 1916. A "Convention between the United States of America and the United Mexican States for the Protection of Migratory Birds and Game Animals" was signed at Mexico City, February 7, 1936; ratified by the United States on October 8, 1936, and by Mexico on February 12, 1937; and proclaimed on March 15, 1937 (50 Stat. 1311).

Among other important treaties relating to wildlife is the "Whale Treaty." The "Convention for the Regulation of Whaling" was signed by representatives of 26 countries, including the United States, at Geneva on March 16, 1932, and was approved for ratification by the United States Senate on June 10, 1932. The enabling act put the treaty into effect on May 1, 1936. An enabling act may give authority for action, but may neglect appropriations for operations. Such is the case with the Whaling Treaty Act. The important Fur Seal Treaty has heretofore been mentioned.

On October 12, 1940, in the Pan-American Building at Washington, D. C., representatives of 13 American republics signed the "Inter-American Convention on Nature Protection and Wildlife Preservation." Since then others have approved. Now 17 have signed the pact. When this treaty is completed and in operation, it should aid materially in the protection of many forms of wildlife, more especially of birds, such as some of the curlews and plovers, that might migrate between the two continents.

*Permanent refuges, sanctuaries, parks, primitive or wilderness areas,* or whatever you may call them, carefully selected and maintained as the optimum habitat for the species, are essential for the preservation of endangered wildlife. By refined definition the terms refuge, sanctuary, park, and primitive area have distinct and different meanings. Sometimes a refuge is called a preserve, reservation, or range. Often, however, in actual usage in proper names, any one name may apply to an area established for the preservation of nature, including wildlife, or primarily for saving a species. The old adage "What's in a name?" here applies. All of them serving for wildlife preservation, we find such as the Wichita Mountains Wildlife Refuge in Oklahoma; the Desert Game Range in Nevada; the Thelon Game Sanctuary in Canada; the Yellowstone National Park in Wyoming; the Kruger National Park in the Union of South Africa; the Parc National Albert in the Belgian Congo; and the Sierra Primitive Area in California.

Frequently, in order to insure suitable environment, a refuge is established on an area including the remnant of a species, and from that remnant as breeding stock effort is made to increase the population. Several refuges in the United States have been established in this way, such as the Sheldon National Antelope Refuge and the Charles Sheldon Antelope Range, Nevada, for prong-horned antelopes; the Red Rock Lakes National Wildlife Refuge, Montana, for trumpeter swans; the National Elk Refuge in Wyoming, and the National Great White Heron Refuge in Florida. Often transplantation of stock to a suitable area is necessary. This was the case in the establishment of bisons on the National Bison Range, Montana; muskoxen on the Nunivak Island National Wildlife Refuge, Alaska; bisons, elks, and prong-horned antelopes on the Wichita Mountains National Wildlife Refuge, Oklahoma; and eastern wild turkeys on Bull's Island, South Carolina.

*Improvement of habitat,* always based on research as to the needed environment, may change living conditions of a small population of a species so as to be the determining factor in its preservation. Artificial means thus applied for wildlife restoration should tend to restore the natural environment of the species or create adaptable substitutes. The means are many and include various types of water restoration; change in vegetative types used by wildlife for food and cover; creation of nesting sites; and control of predators and parasites, often necessary when a wildlife type is nearing the vanishing point.

*Domestication and cross-breeding* have been suggested as having a place in saving an endangered wildlife species, but these methods should be employed only as a last resort. Species so treated for many generations, such as the dog, the cat, the horse, the water-buffalo, the ox, the sheep, the chicken, the turkey, and others, have all lost the characteristics of the wild ancestral stock and developed into many varieties. Fur-farming may save the silver fox, a color variation of the red fox, but in so doing it may so change its characteristics through rearing that the native type would vanish. In order to save the European bison, or wisent, the cross-breeding of it with an old-lineage strain of domestic cattle has been practiced in Germany and with the American bison in the Ukrane, Union of Soviet Socialist Republics.

The photographs are from the files of the United States Fish and Wildlife Service. All maps were prepared by Mrs. Katheryn Tabb, of Biological Surveys, Fish and Wildlife Service.

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New York, New York.

American Committee on International Wildlife Protection,
Museum of Comparative Zoology,
Cambridge, Massachusetts.

American Ornithologists' Union,
Dr. Lawrence E. Hicks, Secretary,
Ohio State University,
Columbus, Ohio.

American Society of Mammalogists,
Dr. Emmet T. Hooper, Secretary,
University of Michigan,
Ann Arbor, Michigan.

American Wildlife Institute,
Washington, D. C.

Comité Belge pour la Protection de la Nature,
Brussels, Belgium.

Emergency Conservation Committee,
734 Lexington Avenue,
New York, New York.

Fish and Wildlife Service,
U. S. Department of the Interior,
Chicago, Illinois.

National Audubon Society,
1006 Fifth Avenue,
New York, New York.

National Park Service,
U. S. Department of the Interior,
Chicago, Illinois.

Office International pour la Protection de la Nature,
Brussels, Belgium.

Society for the Preservation of the Fauna of the Empire,
Hertford, England.

*Biological Surveys*, U. S. Fish and Wildlife Service, Washington, D. C

# THE COTTONTAIL AND THE WEATHER

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During the winter of 1941-42, a hundred cottontail rabbits were trapped near Prairie du Sac, Wisconsin. The daily catch through a period of three months shows fluctuations which seem to correspond to fluctuations in barometric pressure.

A number of authors have noted increased catches or greater activity in mammals during certain types of weather, but none has suggested that these responses might be in phase with some one component of the weather. Bole (2) has pointed out that sudden peak catches of *Blarina* and *Sorex fumeus* often occurred on cool humid nights preceding or following rain. The writer has had similar experiences in trapping small mammals. Burt (3) believed that dark rainy nights produce better catches of *Peromyscus leucopus* than clear moonlit nights. Allen (1) thought the activity of fox squirrel in winter to be conditioned by temperature and snow depth. Studying the same species, Hicks (5) noted that extremes of temperature and the character of the sky affected the degree and time of their activity. Ingles (6) found that the Audubon cottontail (*Sylvilagus a. audubonii*) preferred clear nights and days, and that they were less active during windy rainy weather.

Had these investigators analyzed their observations or catches in relation to daily changes in barometric pressures, they perhaps might have found clearer correlations.

*Methods and materials.*

The daily record of rabbit catches was made while censusing the rabbits in 65 acres of woods and brush in Westpoint Township, Columbia County. Fifteen to 40 treadle box traps were employed during the two trapping periods: November 23 to

December 21, and January 6 to February 13. The traps were moved whenever their efficiency in catching unbanded rabbits suffered a noticeable drop. During a total of 2100 trap nights, 67 rabbits were caught, ear-tagged, and released. A total of 100 catches including repeats was made.

Carrots were the principal bait, though ear corn, apples, and other foods were experimented with occasionally.

The daily catch was then plotted and compared with temperature, precipitation, wind direction, cloudiness, relative humidity, and barometric pressures. Of these six aspects of weather, none showed any striking parallelism with the rabbit catch except barometric pressure.

Data on precipitation, direction of prevailing winds, character of the sky, and temperatures were recorded by the weather station at the Prairie du Sac dam. Relative humidity and barometric pressures were obtained from the Madison weather bureau, twenty-five miles distant.

*Results.*

I here assume that rabbits entered the traps when they were active or hungry or both, and that failure to catch rabbits indicates cessation or diminution of activity or hunger.

The relation between the catch and barometer appears in the second and third graphs of Figure 1. The first and third graphs indicate no visible relation to temperature or depth of snow.

The highest catch per night was five. This is probably too small a figure to measure the *degree* of catchability, but not too small to show the alternation of catches and failures. On nights of low barometer, an average of 0.5 rabbits was caught; while on nights of high barometer, the average catch was 2.5 rabbits. Barometer troughs thus seem to correlate with failure or near-failure; barometer peaks with catches. However, the height of the barometer alone is of no significance, for a scattergraph of all pressure values plotted against all catches produced no discernible relationship. On the other hand, when daily *change* in pressure was plotted against catches, a relation was evident.

This relation is most pronounced in January and February. During early winter the correlation is vague or contradictory.

Statistical analysis failed to confirm the correlation. This

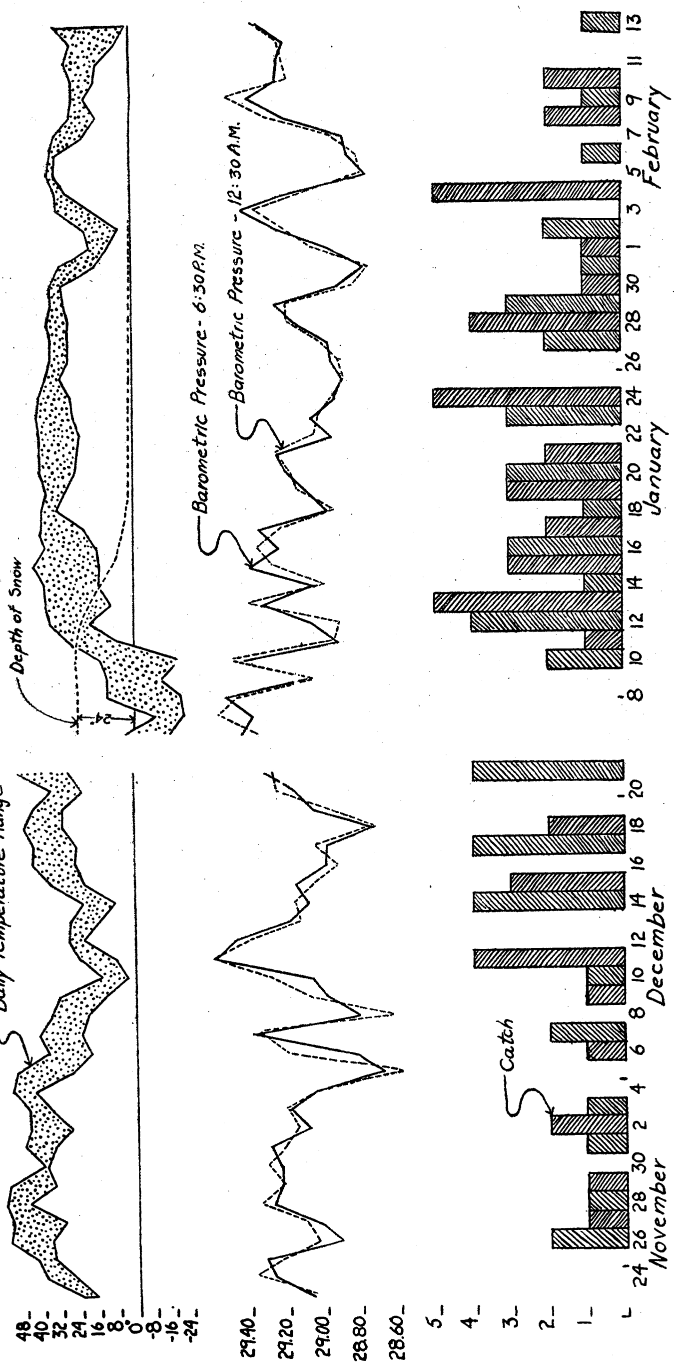


FIGURE 1. Relation of barometric pressure to rabbit catch. Lack of relation to temperature is also shown.

may, of course, be due to its vague definition in time, or to the numerical paucity of the data. It can only be claimed that the relation probably exists, and is worthy of more intensive investigation.

*Discussion.*

Changes in barometric pressures usually denote the passage of cyclonic storms. Passing over a given locality, these storms produce sequences in the weather lasting from four to six days (13, pp. 198, 238). The northern United States, and particularly that region west of the Great Lakes, has been cited by Petersen (9) as one of the areas creating the greatest autonomic demands on the human body, as it lies in the principal path of the cyclonic storms that sweep eastward across the country. Such a relationship between the body and barometric pressure likely holds true for all warm-blooded animals inhabiting areas of meteorological stress.

Dr. Mossman, of the Department of Anatomy at the University of Wisconsin, while making a study of their anatomy, collected over a thousand squirrels in an eight-year period. His field experiences in collecting these squirrels lead me to believe that the fox and gray and red squirrels are, like rabbits, sensitive to barometric pressures. Mossman repeatedly failed to secure squirrels on days which, to all outward appearances, were ideal for hunting. He noticed that storms of some severity usually occurred during the day following his failures to find squirrels. In such instances the effect of a falling barometric pressure is strongly implied.

A similar awareness of impending weather was demonstrated by a pet chipmunk kept by a woman in New York (New York Times, February 5, 1940). Two days before a blizzard it ran about uneasily in its cage, and when given newspapers which it usually tore up and scattered about the cage, the chipmunk instead quickly carried the pieces into a box and made a nest. By noon the animal had crammed the box full and disappeared, not to reappear until three days later when the blizzard had spent itself.

Entomologists have taken cognizance of the effects of changes in barometric pressures upon insects. Parman (7) writes:

"During the last three years observations have been made on several species of *Muscids* showing that with a rapidly falling barometer they first become nervously active, and then go into a state of partial coma. Some species have a tendency to seek a place of protection at this time, others show this tendency very little but become quiet at a most convenient place."

A most forceful and illuminating account of the stimulating and depressing influence of changes in barometric pressures is given by Fabre (4). He observed two groups of caterpillars under circumstances that constitute in effect a controlled experiment. The caterpillars came out with small rises in the barometer and remained at home when it fell. But what is more significant is that his greenhouse caterpillars behaved much the same as those in the garden, exposed to all the vicissitudes of the environment.

Pictet (11) made a painstaking laboratory study of the relation of barometric pressure to the emergence of butterflies. He found that out of 1758 butterflies which he observed emerge from their chrysalids, 91 per cent emerged when the barometer was falling. The number of eclosions was also directly related to the rate at which the barometer fell. A drop of only one degree (mm. of mercury) was sufficient to cause the butterflies that had completed development to leave their chrysalids. However, if the barometric pressure rose when they were on the point of emergence, the eclosions were delayed until another day when the pressure was again decreasing. A uniform or rising pressure over too long a period resulted in the death of the butterflies within the chrysalids.

Responses of humans to changes in barometric pressure may offer some insight into the problem in other mammals. Although Hippocrates long ago recognized the effect of weather upon humans, only in the last few decades has it been given much attention. Modern research in the physiological effects of weather upon man is exemplified in the work of Petersen (9, 10, et al). Every investigator of wildlife problems should be aware of his studies.

According to Petersen (10), "A change in the oxidation-reduction potential of the tissues does occur in close association with changes in the barometric pressure in the normal person as well as in the sick individual." He points out that perhaps ionization and electrical charge may be even more important factors, but that at the present time they are more difficult to determine. He suggests "that the organism may react with an increase in blood pressure, and consequently with a feeling of well-being, to an air mass that will present increasing barometric pressure, lessened humidity, and bright sky even *when the change in temperature may be negligible.*"

Though animal rhythms have been reviewed by recent authors (8, 12, 14) it has not been suggested that changes in barometric pressures may produce fluctuating activity rhythms in animals. On the basis of the limited evidence here presented the writer suggests the existence of a pressure-activity rhythm in many species of small mammals.

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# A NEW WISCONSIN METEORITE

RALPH N. BUCKSTAFF

This Meteorite was found by Albert F. Bonnin while plowing on his farm in Section 18, in the Township of Angelica, Shawano County, Wisconsin, latitude 44°15′ north and longitude 88°15′ west. This township is south and east of the city of Shawano. The iron was found sometime during the month of October 1916. Mr. Albert Bonnin gave this information in answer to a questionnaire sent to him regarding his find. The meteorite weighs 32 pounds 11¼ ounces.

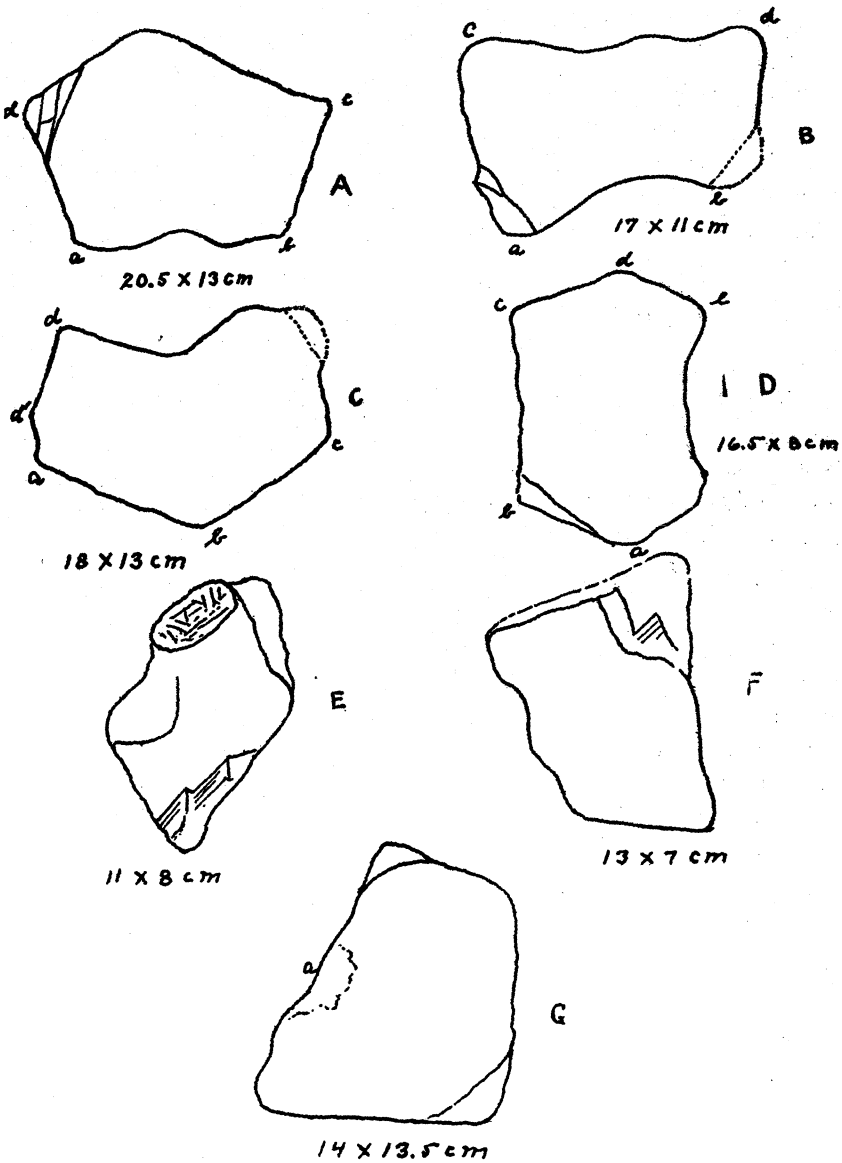
## EXTERNAL APPEARANCE OF METEORITE

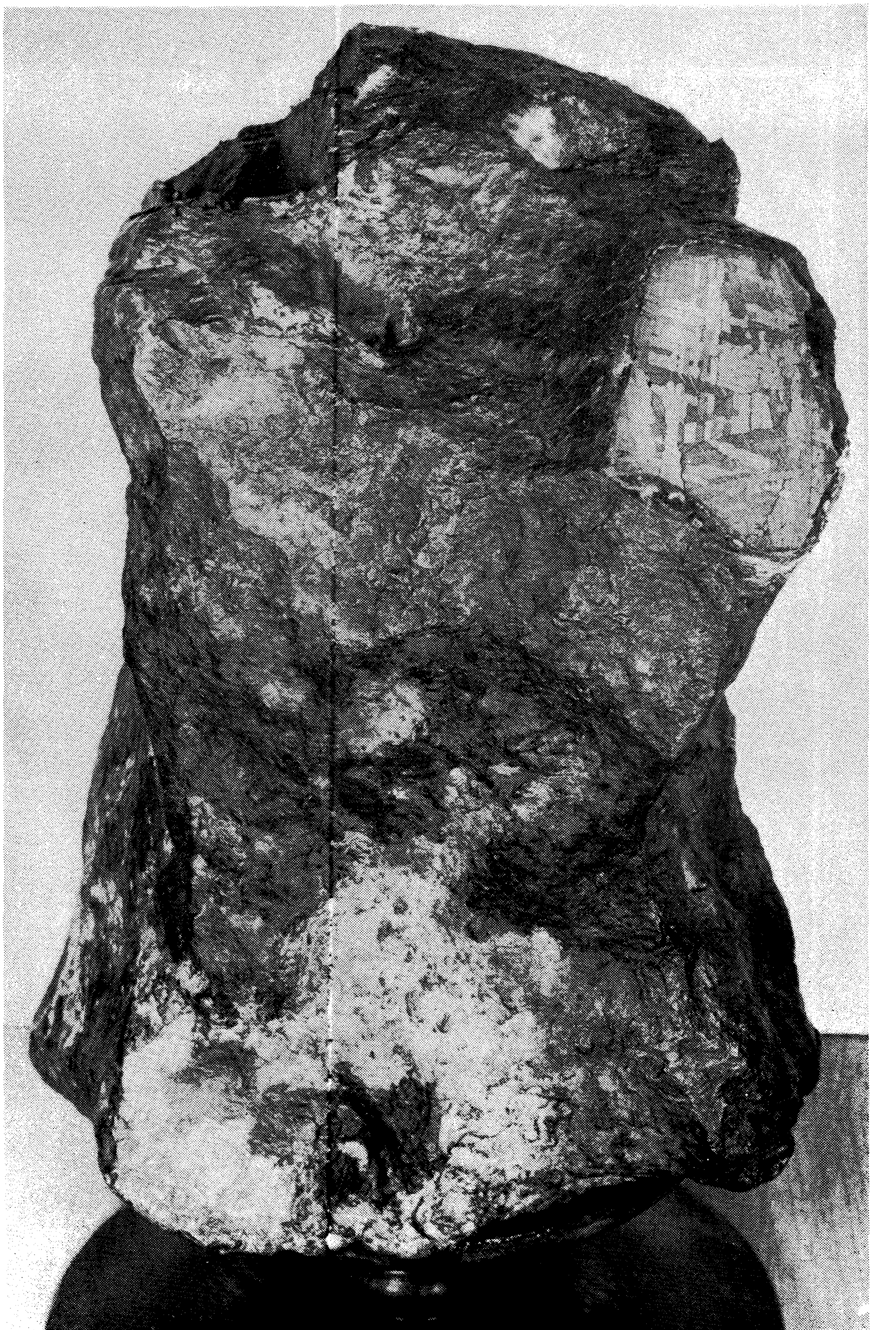
The meteorite is an angular mass. Its greatest dimensions are length 20.5 cm, width 15.3 cm, thickness 15 cm. This iron has seven sides or faces, which we will call A, B, C, D, E, F, & G, none of these being parallel with each other. The edges bounding the sides for the greater part are quite angular.

*Face A*: The surface of this face is very much oxidized, none of the original crust being left. Large weathered pittings cover most of this side. The face measures 20.5 cm x 13 cm. Its color is a very dark brown. At one end of this side, a large angular fragment has been broken off thus exposing the interior arrangement of the laminae. These intersect at angles of 60° and 120°. The outer edges d, a, b, and a, b, c, form angles of 120°.

*Face B*: This surface is much oxidized, and deep brown, nearly black in color. Edge a, b is very much concaved but edge c, d is both concave and convex. The length of the face is 17 cm, width 11 cm, but at narrowest point 8 cm. Angle a,c,d equals 60°.

*Face C*: This surface shows a number of deep pits. Original crust covers a part of the face. Lines of flow, and minute pittings in places may be seen with the aid of a hand lens. The color of this surface is a uniform tobacco brown with a semi-gloss sheen. The outline of this face is very angular. Angle b, a, d is 90 degrees and angle a, b, c is 128 degrees. Edges a, b





and d, f are parallel. Face C measures 18 cm long and 13 cm wide.

*Face D*: Angular in outline, the surface is much oxidized. Edges a, b and d, e are parallel. Angle a, b, c equals 120 degrees. The upper third of the face is fractured exposing laminae. The plain surfaces of the laminae thus exposed forms a trihedral, whose intersecting faces form angles of 60 degrees and 120 degrees.

*Face E*: The edges of this face are parallel and the size of its surface 11 by 8 cm. A little of the original crust is still visible, and under magnification shows minute pittings. A small piece has been broken from one corner of the side. The fracture has followed the laminae, giving the edge a straight line.

*Face F*: A small portion of the original crust remains on this face. Part of this surface shows an angular fracture. Edges of the face form angles of 60 degrees, 90 degrees, and 120 degrees. One of the edges is quite wavy. The color of the surface is a uniform dark tobacco brown with a semigloss sheen in places. This face measures 7 by 13 cm.

*Face G*: This measures 14 by 13.5 cm. Around area "a" may be seen a part of the original crust showing minute pits and lines of flow. The face is angular in outline. Like the preceeding faces the angles formed at the corners are 60 degrees and 120 degrees.

Points of taenite, and in one place some bands of this metal, show through the oxidized surface.

## The Interior Structure

A slice of this iron measuring 5.2 by 3.1 cm shows upon etching, with a 10% solution of nitric acid, the typical Widmanstatten figures. One set of laminae intersects at angles of 109°28′, another group at 75°, while a third set has intersecting angles of 68°. Laminae are 1 to 2 mm wide and from 6.5 to 20 mm long. Their sides for the most part are ragged in outline. The ends are angular, round, and a few are serrated.

The taenite is not very conspicuous, being a bright nickel color but only a fraction of a millimeter in thickness. The kamacite for the most part is banded by taenite. This metal, however, disappears in places and leaves the kamacite with no surrounding taenite.

A variety of structures are found in the kamacite, the commonest being that hatched with Neumann-like lines. These intersect at angles 60°, 90°, and 120°.

A few plates have a series of parallel, fine lines crossing them at oblique angles to the sides. All these markings seem to have a slight blurred appearance when seen under low magnification.

Some of the kamacite appears to be structureless. In some places it is flaked with pin-like points of taenite. In a few places the kamacite shows a grouped structure. This formation consists of a series of parallel plates a fraction of a mm in thickness. The ends of these plates give the laminae a serrated appearance.

Scattered over the surface are rectangular and triangular fields of plessite. A large part of these fields show a granular structure. A few have a banded appearance.

There are a number of triangular and rectangular areas, ranging in size from 1 x 1.5 to 1.5 x 3 mm. These have a dark background. Scattered over this surface is a granular-like metal structure. Some of the grains are irregular, others round, looking more like dots. One of these rectangular areas is bounded by a thin band of taenite.

Lying diagonally in the surface of this slab is an inclusion of pyrrhotite, measuring 1 cm long, 1 mm wide at the broad end, and tapering to a point at the other end. Flakes of taenite cross this inclusion at nearly right angles to the sides. Bordering the edge of the pyrrhotite are two irregular nodules of graphite. Grouped about this inclusion are irregular plates of kamacite, but their arrangement does not form any definite pattern.

Minute grains and angular inclusions of a black glossy substance appear on the surface. The angular formations are at the intersection points of a few of the laminae. Cracks taking zigzag courses between some of the kamacite plates are filled with this same black substance. The taenite bands along one side, near the outer edge, have been altered to iron oxide. In other places these bands can be traced 'way out to the edge and do not show any alteration whatsoever.

The etched surface when seen under a certain angle of illumination shows rather coarse pits widely scattered over it.

An analysis of one half ounce of the sawings of the meteorite, made by E. J. Schneider of the Oshkosh High School Chemistry department, gave the following results:

| | |
|---|---|
| Iron | 95.5% |
| Nickel | 4.5% |
| Manganese | .5% |
| | 100.5 |

## Conclusion

The angular outline of this meteorite shows that it was probably broken from a larger mass, the fracture following cleavage planes. The outline thus formed resembles the same angular pattern as shown by the Widmanstatten figures. Two distinct sets of Widmanstatten figures are seen on the etched surface.

Under the Rose-Churmak-Brezina system of classification, iron octahedrites whose lamellae measure 1.5 to 2.0 mm in thickness are classed as Coarse Octahedrites. We have seen by the description of the meteorite, that it belongs to this group and we will class it Coarse Octahedrite (Og). We will propose the name of Angelica for this new siderite, as it was in this township in Shawano County, Wisconsin, that it was found. This is the eighth meteorite from our State and the fifth one of this kind. Lack of oxidation of the taenite bands near the surface would indicate a rather recent fall. The officials of the Oshkosh Public Museum wish to thank Dr. Ira Edwards for his help in obtaining this specimen for us.

This celestial wanderer from outer space will be added to the permanent meteorite collection in the Astronomical Department of the Oshkosh Public Museum.

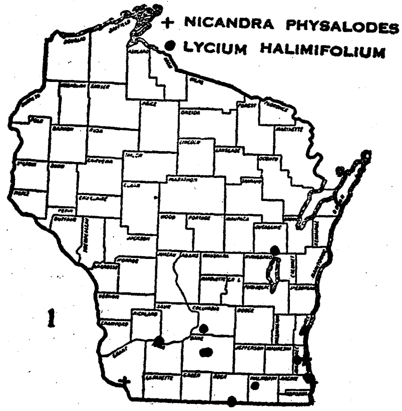
# PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN. XXXI. SOLANACEAE

NORMAN C. FASSETT

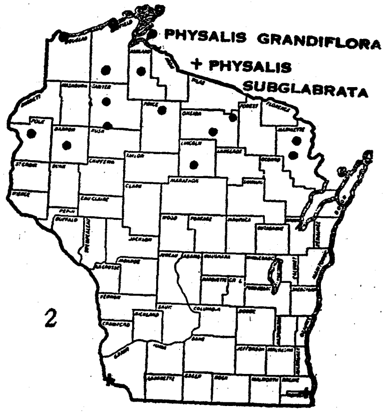
The maps here presented are based on the material in the herbaria of the Milwaukee Public Museum and the University of Wisconsin, and in the private herbarium of Mr. S. C. Wadmond. Following the practice initiated by C. C. Deam in his Flora of Indiana, the genera are numbered in agreement with the Genera Siphonogamarum of dalla Torre & Harms.

Many members of the Nightshade Family in Wisconsin are adventive from the Old World or from South America, and most of the native species occur in open sandy soil or as weeds. The only real difficulties in determination are in the genus *Physalis*, which is so in need of revision that this treatment must be considered as only provisional.

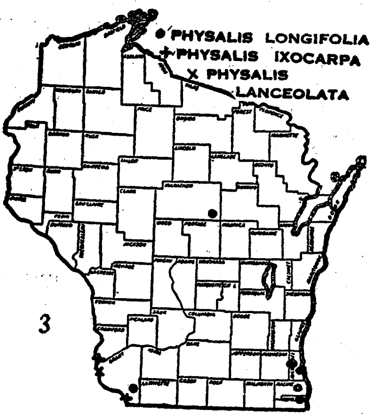
*a*. Flowers borne singly in the leaf axils
  *b*. Corolla yellow, at least toward the center, spreading and wider than long; annuals and perennials ............7401. *Physalis.*
  *b*. Corolla white, blue, yellow or reddish, tubular and longer than wide; annuals
    *c*. Plants without sticky hairs
      *d*. Flowers about 2.5 cm. long; fruiting calyx enlarged and papery, enclosing the berry ....................7377. *Nicandra.*
      *d*. Flowers 1.5-9 cm. long; fruiting calyx not enclosing the prickly pod ...........................7415. *Datura.*
    *c*. Plants with sticky hairs
      *e*. Leaves mostly 1 dm. or more long ................7434. *Nicotiana.*
      *e*. Leaves less than 1 dm. long ........................7436. *Petunia.*
*a*. Flowers in racemes or several in a leaf axil, rarely solitary on a leafy branch
  *f*. Stems shrubby; leaves 1.5 cm. or less wide, tapered at base, not toothed or lobed ...............................7379. *Lycium.*
  *f*. Stems herbaceous, or if shrubby the leaves wider, rounded at base and often lobed ........................7407. *Solanum.*


+ NICANDRA PHYSALODES
● LYCIUM HALIMIFOLIUM

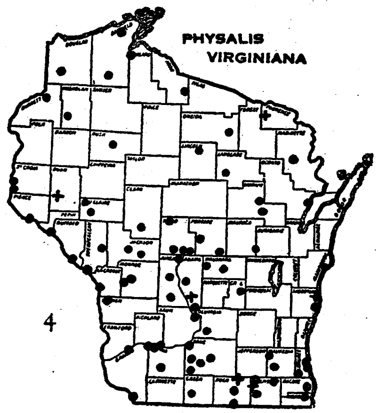
1


● PHYSALIS GRANDIFLORA
+ PHYSALIS
SUBGLABRATA

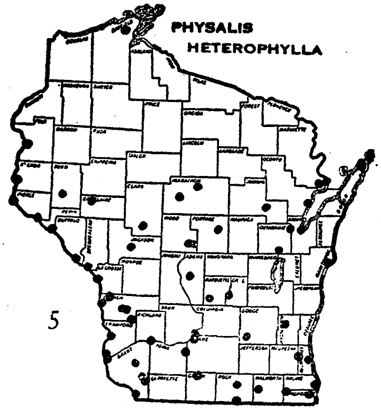
2


● PHYSALIS LONGIFOLIA
+ PHYSALIS IXOCARPA
X PHYSALIS
LANCEOLATA

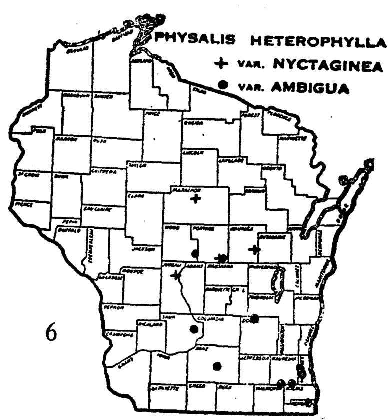
3


PHYSALIS
VIRGINIANA

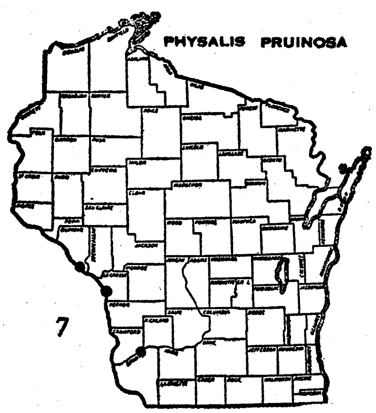
4

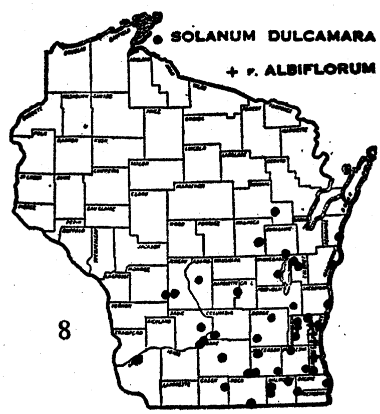

PHYSALIS
HETEROPHYLLA

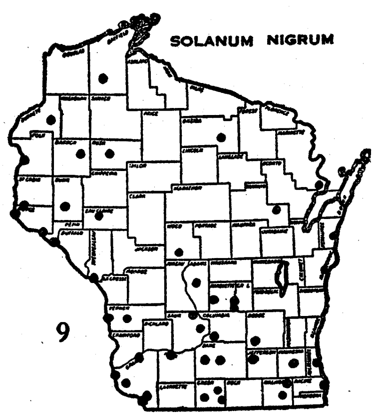
5

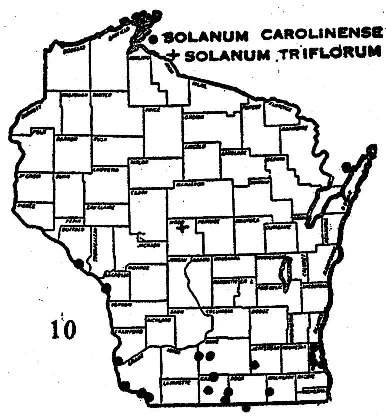

PHYSALIS HETEROPHYLLA
+ VAR. NYCTAGINEA
● VAR. AMBIGUA

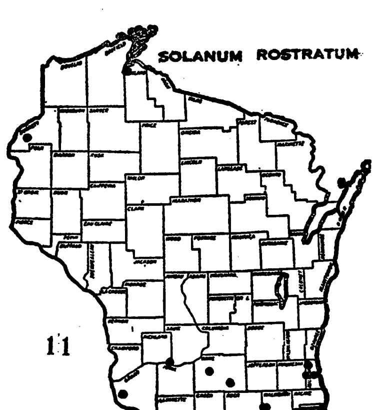
6

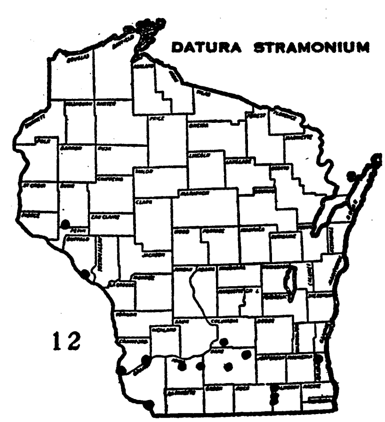

PHYSALIS PRUINOSA
7


● SOLANUM DULCAMARA
+ F. ALBIFLORUM
8


SOLANUM NIGRUM
9


● SOLANUM CAROLINENSE
+ SOLANUM TRIFLORUM
10


SOLANUM ROSTRATUM
11


DATURA STRAMONIUM
12

### 7377. NICANDRA. Apple-of-Peru

N. PHYSALODES (L.) Pers. Map 1, crosses. Collected by Lapham in Milwaukee and Hale in Racine, and recently in a corn field at Potosi; introduced from Peru.

### 7379. LYCIUM. Matrimony-vine

L. HALIMIFOLIUM Mill. Map 1, dots. Sometimes persisting after cultivation or spontaneous in waste places in southern Wisconsin; introduced from Europe.

### 7401. PHYSALIS. Groundcherry

*a.* Corolla white with pale yellow center; fruiting calyx closely fitted to the berry and open at the throat; annual ........ *P. grandiflora.*
*a.* Corolla yellow; fruiting calyx inflated, ribbed
  *b.* Hairs on the peduncles appressed, or else less than 0.10 mm. long; leaves nearly or quite glabrous
    *c.* Hairs on peduncles upwardly appressed, about 0.25 mm. long; perennials
      *d.* Leaves ovate, 1½ times as long as broad, sparsely pubescent above ........ *P. subglabrata.*
      *d.* Leaves lanceolate, 3-5 times as long as broad, glabrous except sometimes on margin and midrib ........ *P. longifolia.*
    *c.* Hairs on peduncles downwardly appressed, or else less than 0.10 mm. long; annual ........ *P. ixocarpa.*
  *b.* Hairs on peduncles spreading or somewhat curved downward, 0.25 mm. or more long; leaves mostly pubescent
    *e.* Lower surfaces of veins with usually ascending hairs not any more numerous than those on the leaf-surface between the veins; leaves usually several times as long as broad, wedge-shaped at base; perennials
      *f.* Veins becoming obscure toward the margin of the leaves; pubescence rather copious, usually all stiff and less than 0.5 mm. long and curved upward on the peduncles and downward on the leaves, but in less common (often broader-leaved) forms longer and spreading; calyx deeply sunken about the base ........ *P. virginiana.*
      *f.* Veins recurving toward the margin to join with the one below; pubescence sparse; calyx not deeply sunken at base ........ *P. lanceolata.*

*e.* Lower surface of veins with mostly spreading hairs more numerous than on the leaf-surface between the veins; leaves broadly ovate, less than twice as long as broad, cordate at base in all but one variety

*g.* Pubescence of stem and leaves shining when viewed under a lense; filaments dilated; calyx-lobes usually triangular with essentially straight sides; anthers about 3 mm. long; perennials

*h.* Stem with copious gland-tipped hairs about 0.5 mm. long, which are usually accompanied by flat jointed hairs 1 mm. or more long

*i.* Leaves cordate or truncate at base ..............*P. heterophylla.*

*i.* Leaves broadly wedge-shaped at base ................................ *P. heterophylla* var. *nyctaginea.*

*h.* Stem with copious flat jointed hairs 1 mm. or more long, which are sometimes gland-tipped, but are not accompanied by gland-tipped hairs about 0.5 mm. long ......................................*P. heterophylla* var. *ambigua.*

*g.* Pubescence dull; filaments thread-like and not swollen; calyx-lobes tapering to a tip, with curved sides; anthers 1-2 mm. long; annuals ......*P. pruinosa.*

1. P. GRANDIFLORA Hook. Map 2, dots. In clearings, on shores of streams, and in other recently disturbed habitats in northern Wisconsin, south to Polk, Lincoln and Door Counties.

2. P. SUBGLABRATA Mackenzie & Bush. Map 2, crosses. In sandy woods along the Mississippi River at Cassville, Grant County, apparently as a migrant up the river, and as a weed in cultivated fields in Kenosha County.

3. P. LONGIFOLIA Nutt. Map 3, dots. Along railroads in Milwaukee County, also collected at Platteville, Grant County, and perhaps across southern Wisconsin as a railroad weed. Collected in 1942 along a roadside in Marathon County.

4. P. IXOCARPA Brotero. Map 3, crosses. Collected in 1895 at Prairie du Chien, Crawford County, and in 1911 in southern Grant County. Perhaps an escape from cultivation.

5. P. VIRGINIANA Mill. Map 4. A common plant in sandy places. In the originally forested areas of the northern part of the state it was probably much less abundant formerly than at present; for example, the collection in Iron County was in an isolated colony of prairie plants which were obviously adventive from regions to the south or the west.

Gray's Manual, following Rydberg (Mem. Torr. Bot. Club 5: 343-345. 1896) states that the commoner form has very short recurved hairs, while a less common form, nomenclatorially the type, has longer spreading hairs. This is the case in Wisconsin; on the map the individuals with longer pubescence are indicated by crosses. These individuals often have wider leaves than do those with the shorter hairs.

6. P. LANCEOLATA Michx. Map 3, x. A plant described in the preceding key, and probably belonging to this species, was collected at Wyalusing, Grant County.

7. P. HETEROPHYLLA Nees. Map 5. A common species, mostly in sand and rarely in heavier soils, in the southern half of the state. It has probably become more common at its northern limits since the forests have been cut and the land cultivated. The collection in Bayfield County was at Lenawee, the site of an old lumber town, in 1917.

The two following varieties are treated as species by Rydberg, Flora of the Prairies and Plains, and by Deam in his Flora of Indiana. As they occur here they do not seem to be clear-cut entities. The pubescence of the stem is very variable, and the presence or absence of the short gland-tipped hairs seems scarcely of specific rank. Leaf shape, also, is exceedingly variable, and there is no definite line between those of the cordate type and those of the cuneate type.

P. HETEROPHYLLA var. NYCTAGINEA (Dunal) Rydb. Map 6, crosses. Occasional in central Wisconsin.

P. HETEROPHYLLA var. AMBIGUA (Gray) Rydb. Map 6, dots. Occasional from Sauk and Brown Counties southeastward.

8. P. PRUINOSA L. Strawberry Tomato. Map 7. Rare along the Mississippi and lower Wisconsin Rivers. It was collected in LaCrosse in 1861.

## 7407. SOLANUM. Nightshade

*a.* Plants without prickles or stellate hairs
- *b.* Stems long, reclining, climbing or trailing in the water; flowers purple or rarely white; berries red; perennial ........ 1. *S. Dulcamara.*
- *b.* Stems branched near the base, spreading or erect; flowers white or pale lilac; berries black or green; annuals

c. Leaves not lobed; mature berries black ................ 2. *S. nigrum.*
c. Leaves pinnately lobed; mature berries green ............................................ 3. *S. triflorum.*
a. Plants with prickles and stellate hairs
d. Leaves cut usually less than half way to the midrib, with broad triangular lobes; flowers violet, rarely white; berry not enclosed by the scarcely prickly calyx; perennial ........................................ 4. *S. carolinense.*
d. Leaves cut nearly or quite to the midrib, with rounded lobes; flowers yellow; berry enclosed by the densely prickly calyx; annual ..................................... 5. *S. rostratum.*

1. S. DULCAMARA L. Bittersweet; Matrimony Vine. Map 8. Common in southern and eastern Wisconsin in a variety of habitats, including pastured tamarack bogs, brooksides, limestone cliffs, dooryards, hedges, etc. Sometimes the stems trail in the water. Although usually described as naturalized from Europe, it often occurs in habitats that suggest it is a native.

White-flowered individuals, which have been described as f. ALBIFLORUM House, N.Y.State Mus. Bull. no. 254: 613. 1924, are indicated by crosses on the map, and appear to be centered on a region in Washington, Ozaukee and Milwaukee Counties; this apparent localization may be only an accident of collecting.

Numerous varieties, forms, etc., have been named, based on degrees of pubescence; see, for example, Hegi, Ill. Fl. Mitt-Eur. 5: 2590. The most pubescent extremes in North America have been called var. *villosissimum* Desv. (Fernald, Rhodora 24: 202. 1922), var. *pubescens* R. & S. and var. *canescens* Farwell (Papers Mich. Acad. Sci. 2: 39. 1922). The plants in Wisconsin vary from nearly glabrous to velvety-leaved and pilose-stemmed.

2. S. NIGRUM L. Black Nightshade. Map 9. In pastured woods, gardens, etc., mostly in southern Wisconsin but sometimes northward; usually listed as a native but appearing as if introduced in this region.

3. S. TRIFLORUM Nutt. Map 10, cross. Collected once along a railroad at Arpin, Wood County, where it was adventive, probably from the west.

4. S. CAROLINENSE L. Horse Nettle. Map 10, dots. Roadsides, disturbed sandy soil, cultivated fields, etc., locally in southern Wisconsin.

5. S. ROSTRATUM Dunal. Buffalo Bur. Map 11. Adventive in waste places, mostly in southern Wisconsin but occasionally northward; an immigrant from the West.

### 7415. DATURA. Stramonium; Jimson-weed

1. D. STRAMONIUM L. Map 12. In waste places, farmyards, etc., in southern Wisconsin and the Mississippi River valley; naturalized from tropical regions. Includes *D. Tatula* L.; see Deam, Flora of Indiana 831. 1940.

2. D. METAL L. This differs from *D. Stramonium* in having leaves entire and closely puberulent on the lower surface; it is represented in Wisconsin only by a single collection by T. J. Hale, probably near Racine about 1860.

### 7434. NICOTIANA. Tobacco

N. RUSTICA L., Wild Tobacco, with flowers about 1.5 cm. long and upper leaves petioled, has been collected in Milwaukee. N. TABACUM L., the cultivated Tobacco, with flowers 4-5 cm. long and sessile leaves, is raised in southern Wisconsin and may occasionally escape.

### 7436. PETUNIA

Members of this genus occasionally escape from cultivation; P. AXILLARIS BSP. has been collected on a waste heap in Milwaukee, and P. HYBRIDA Vilm. on a railroad track in Madison.

# NOTES ON WISCONSIN PARASITIC FUNGI. III.

H. C. GREENE

These notes are based chiefly on collections made during the season of 1942. Weather conditions were exceptionally favorable for development of parasitic fungi and many unusual things were found. I am particularly indebted to Professor Charles Chupp of Cornell University who this year, as in past years, has promptly and painstakingly assisted me in the identification of many Cercosporae.

Although BREMIA LACTUCAE Regel is a common and well-known parasite of LACTUCA SATIVA there were no Wisconsin specimens on this host in the Herbarium. Trelease first reported it for the state sixty years ago. The omission has been rectified with a specimen taken in June at Eagleville, Waukesha Co.

*Rhus canadensis* (cult.) in Madison was heavily infected with Oidium, but development of perithecia did not occur, perhaps because of rapid drying and early fall of the attacked leaves.

The curious and striking form, MICROSPHAERA ALNI (DC.) Wint. var. LUDENS Salm., occurred on *Desmodium canadense* at Eagleville, Waukesha Co., in September. A single earlier collection was made by Davis at Nekoosa, Wood Co., in 1919.

Immature Phyllachora on *Panicum virgatum,* collected at Madison in September, is probably PH. GRAMINIS (Pers.) Fckl. Dr. C. R. Orton considers that it is extremely likely that a previous report of PH. PUNCTA (Schw.) Orton on this host in Wisconsin is erroneous.

In a preceding publication by this writer (Trans. Wis. Acad. Sci. *34*: 91, 1942) *Bouteloua curtipendula* was reported as a host of PHYLLACHORA GRAMINIS. Dr. Orton finds this to be PH. BOUTELOUAE Rehm. It is the only mature Wisconsin collection on this host.

Dr. Orton has examined material, from the University of Wisconsin Herbarium, of *Melica striata* bearing a fungus labelled PHYLLACHORA MELICAE Dearn. & House. He states that he sees no reason for recognizing PH. MELICAE as distinct from PH. GRAMINIS.

A fungus which is presumably PHYLLACHORA LESPEDEZAE (Schw.) Sacc. has been found on *Lespedeza capitata,* in 1940 at Paoli in Dane Co., and in 1942 at Lake Lulu in Walworth Co. Leaves from the Walworth Co. collection were submitted to Dr. Orton who states that all the asci appear to be tetrasporic, confirming my observation. It was noted that there are two types of stromata, small ones containing the mature asci, and larger bodies, lacking asci, but with areas of differentiation suggesting the beginning of an ascigerous stage. Dr. Orton thinks that from the general appearance there is only one fungus concerned, and he suggests that there may be dual stages of development. Thus, the small bodies with asci may be an early stage, primarily for summer propagation, while the large bodies possibly will develop during the winter for spring propagation. In this connection I did overwinter some of the leaves from the Paoli collection, but failed to obtain further development. Two later collections made in September 1942 at Madison, Dane Co., and at Eagleville, Waukesha Co., show only the larger immature stromata. It is of no little interest that Clevenger (Jour. Mycol. *11*: 161, 1905) also found a 4-spored Phyllachora on *Lespedeza capitata* and on *L. repens.* Dr. Orton believes that sufficient search probably will eventually reveal an octosporic form for this fungus.

Plakidas (Mycologia *34*: 27, 1942) has shown that CLADOSPORIUM HUMILE Davis, established by the late J. J. Davis on Wisconsin material on *Acer rubrum* and *A. saccharinum,* is the conidial stage of VENTURIA ACERINA Plakidas on *Acer rubrum.*

PLEOSPORA sp. has been found on culms of living *Cinna latifolia,* in late fall. Closely associated in identical lesions is HENDERSONIA sp. with conidia 3-6 septate, 20-30 x 2.5-3.5$\mu$. It seems possible that the Hendersonia is the imperfect stage f the Pleospora. The parasitism of both is doubtful and any final conclusion awaits the collection of further material.

PLEOSPORA sp. occurred in abundance on seedlings of *Artemisia caudata* at Madison, September 1942. This may be parasitic, for only the upper portions of the leaves are involved.

USTILAGO LORENTZIANA Thuem. on *Hordeum jubatum* was observed and collected in abundance by Professor R. I. Evans in June, near Fall Creek, Eau Claire Co. This seemingly is, or has been, rare in Wisconsin, for the late Dr. Davis who collected intensively throughout the state over a period of many years has noted that he never observed it in the field. There is in the Herbarium but one satisfactory earlier specimen from Wisconsin, collected by Melhus at Madison in 1910.

PUCCINIA HIERACII (Schum.) Mart. II was found in small quantity on a single plant of *Hieracium scabrum* at Madison in September. This rust, so common on *Hieracium canadense*, seems to be very rare on *H. scabrum* in Wisconsin. Trelease reported it in 1883, but the only Wisconsin specimen in the Herbarium, previous to the present one, was collected by Davis at Baraboo, Sauk Co., in 1932.

UROMYCES PUNCTATUS Schroet. II occurred on *Astragalus canadensis* in an abandoned nursery in the University of Wisconsin Arboretum at Madison. Earlier collections were made by Davis in 1914 at Bridgeport, Crawford Co., and St. Croix Falls, Polk Co.

In my second series of notes reference was made to the occurrence of ostiolate pycnidia with microcondia of a bacillary type developing on *Panicum scribnerianum*. A similar infection has been found on *Panicum villosissimum* from Fall City, Dunn Co. Coll. L. H. Shinners.

Leaves of *Synthyris bullii* collected at Eagleville, Waukesha Co., have pale brown, ovate spots 4-5 mm. diam., with a narrow dark brown border, bearing flesh-colored, ostiolate pycnidia, about 115-125$\mu$ diam. The ostiole is 20-25$\mu$ diam., delimited by a narrow ring of darker mycelial tissue. The hyaline conidia are small, 4-5 x 1-1.5$\mu$. There seem to be no previous reports of fungi on this host.

PHOMA IOWANA Sacc. collected on *Aster ptarmicoides* at Eagleville, Waukesha Co., August 19, bears pycnidia on both leaves and stems, differing from previous specimens seen by me where leaves only were affected.

CONIOTHYRIUM sp. has been observed on *Evonymus atropurpureus.* The relationship of fungus to host is doubtful, for the spots are not definite, and areas containing the Coniothyrium also bear Alternaria. The dark olivaceous pycnidia are ostiolate, depressed-globose, 80-100$\mu$ diam. Conidia are pale olivaceous, short-cylindric, 3-4 x 5-7$\mu$.

DAVISIELLA (?) in PHYLLACHORA PUNCTA on *Panicum latifolium* from Prairie du Sac has the spores mainly 3-septate, resembling previous specimens on *Andropogon furcatus* and *Muhlenbergia foliosa.*

STAGONOSPORA INTERMIXTA (Cke.) Sacc. on *Agrostis gigantea* var. *dispar* (*A. alba*). Waukesha Co., Eagleville, July 2. Davis (Trans. Wis. Acad. Sci. *24*: 285, 1929) reported the fungus on *A. alba* from LaValle, Sauk Co., but the specimen is very small, and he chose to delete this host in his "Parasitic Fungi of Wisconsin" (published posthumously in 1942). The Eagleville material is abundant. The pycnidal walls are not particularly well defined, and the conidia, while mostly 7-septate, are somewhat shorter than those of the LaValle collection, running from 30-40 x 3$\mu$.

On *Panicum scribnerianum* found in the vicinity of Lake Lulu, Walworth Co., SEPTORIA sp. (S. GRAMINUM Desm.?) occurred intimately associated with what appeared to be immature PHYLLACHORA PUNCTA. The pycnidia are subglobose, about 150-180$\mu$ in their greatest diam., and touch upon both lower and upper epidermis, without causing any noticeable hypertrophy and without being marked by any spotting of the leaves. The conidia are continuous, long, and very slender, 50-80 x 1-1.5$\mu$, and are discharged on the upper surface, although it is difficult to discern a definite ostiole.

SEPTORIA ANDROPOGONIS J. J. Davis on *Andropogon furcatus* was found at Madison, August 26. This well-marked species is represented on this host only by the original type collection and the present one. The type was taken at Gaslyn, Burnett Co., in 1911. Whether this species has been reported from outside the state is unknown to me.

SEPTORIA LUPINICOLA Dearn. on *Lupinus perennis* has been collected near Sauk City. All previous collections were made many years ago from localities considerably farther north.

SEPTORIA ERYNGICOLA Oud. & Sacc. on *Eryngium yuccifolium* from Madison is not limited to well-defined spots, as in previous specimens from Paoli, but caused extensive necrosis of the leaf tissue.

This writer (Trans. Wis. Acad. Sci. *32*: 83, 1940) reported the collection of SEPTORIA PLANTAGINEA Pass. var. PLANTAGINIS-MAJORIS Sacc. on *Plantago purshii* from Mazomanie. A recent specimen from Madison shows some sporules as long as 45$\mu$, but all very slender and of the same aspect as those of the earlier material.

Davis states in connection with SEPTORIA NOLITANGERE Thuem. that immature perithecia are found in some of the specimens. This refers no doubt to the perithecia of MYCOSPHAERELLA IMPATIENTIS. In 1941 at a station near East Troy, Walworth Co., M. IMPATIENTIS was collected on *Impatiens biflora*. In 1942 SEPTORIA NOLITANGERE was found on this host at the same station. So similar are the lesions that at the time of the second collection it was thought the specimen was Mycosphaerella. It is probable that S. NOLITANGERE is the imperfect stage of MYCOSPHAERELLA IMPATIENTIS.

The fungus on *Veronica arvensis* which is referred to SEPTORIA VERONICAE Desm. is not uncommon in Wisconsin. It develops in systemic fashion on stems, leaves and calyces without forming definite spots. In 1890 at Sharon, Walworth Co., the late J. J. Davis collected a Septoria on *Veronica virginica* which he states was referred to S. VERONICAE Desm. with some doubt by Mr. Ellis. In this collection the pycnidia are borne in definite spots, but the leaves are so discolored that it is impossible to tell what the original color of the spots may have been. In August 1942, at Madison, there occurred a Septoria on *Veronica virginica* (cult.) which, in microscopic section, appears to be the same as that found by Davis. The spots are very definite, black and angular. Judging from the mode of development on the hosts, it seems that perhaps the Septoria on *V. arvensis* should be placed under SEPTORIA GRATIOLAE Sacc. & Speg. and that the one on *V. virginica* should be retained under S. VERONICAE Desm.

SEPTORIA sp. on *Chrysanthemum leucanthemum* var. *pinnatifidum.* Dane Co., Madison, June 26. This form has slender sporules, mostly 20-30 x 1.5-2$\mu$. The brownish-gray spots, extending to and involving the leaf margins, produce a scalloped effect. This fungus may be worthy of specific distinction, but I feel that additional material, preferably from more than one station, should be secured, since it seems apparent that the taxonomy of Septoria on Chrysanthemum is in a state of confusion, and any new species should be firmly backed.

SEPTORIA SOLIDAGINICOLA Pk. has been collected on *Aster umbellatus* at Madison. The only other Wisconsin station at which the fungus has been found on this host is Wind Lake, Racine Co.

SEPTORIA RUDBECKIAE Ell. & Hals. developed in abundance on *Rudbeckia subtomentosa* at Eagleville, Waukesha Co. Davis made one earlier collection on this scarce host in Iowa Co. in 1930. At the same station S. RUDBECKIAE likewise occurred on *Rudbeckia hirta,* also represented by a single previous collection, from Altoona, Eau Claire Co.

A Colletotrichum parasitic on *Andropogon furcatus* and on *Sorghastrum nutans* was found at Madison, September 11, 1942. This is not COLLETOTRICHUM GRAMINICOLUM (*Ces.*) Wils. as I understand it. The clumps of Andropogon and Sorghastrum were growing within a few yards of one another. However, perhaps the close relationship of the hosts, as well as proximity, accounts for the simultaneous infection. The conidia are distinctive, curved Fusarium-like and with a slender curved appendage projecting from the apex. The curve of the appendage follows that of the conidium proper, so that the whole forms almost a semicircle. The conidia are 20-25 x 4-5$\mu$, plus the appendage of about 10$\mu$. The conidophores are closely ranked, very short, less than 10$\mu$. Setae are blackish-brown, straight, slender, with only an occasional septum, variable in length, up to 125$\mu$, 3-4$\mu$ wide, terminating in a rather blunted tip. It is interesting that Davis reported COLLETOTRICHUM GRAMANICOLUM on *Sorghastrum nu-*

*tans* and that examination of his specimen shows the identification to be correct. The fungus is confined to more definite spots than is the case with the recently collected specimens. Certainly two species are involved. My collections may represent a new species, but in view of my limited knowledge of the genus Colletotrichum I do not feel justified in publishing a formal description.

Colletotrichum on *Panicum implicatum* is perhaps C. GRAMINICOLUM. The specimen is scanty, however, and it is possible that the fungus developed saprophytically.

COLLETOTRICHUM sp. occurred on *Smilacina trifolia* at East Troy, Walworth Co. I have not seen a specimen of COLLETORICHUM SMILACINAE Tehon & Daniels, but judging from the description this is a different thing, although most of the microscopic dimensions are similar. Doubtfully parasitic. Davis (Trans. Wis. Acad. Sci. *30*: 1, 1937) expressed the opinion that, in most instances, Colletotrichum found on liliaceous hosts has developed saprophytically.

A robust species of Colletotrichum collected on *Saponaria officinalis* at Madison fails to correspond with either VERMICULARIA COMPACTA Cke. & Ell. or V. SAPONARIAE Allesch. The setae are up to 225$\mu$ long. Doubtfully parasitic on the leaves.

COLLETOTRICHUM GLOEOSPORIOIDES Penz. occurred on fallen leaves of *Allamanda cathartica* var. *hendersoni* in a University of Wisconsin greenhouse at Madison. Possibly parasitic.

MARSONIA CORONARIAE Sacc. & Dearn. on *Pyrus ioensis*. Waukesha Co., Eagleville, September 7. Not common. Previous collections have usually been immature.

RHYNCOSPORIUM SECALIS (Oud.) J. J. Davis found on *Bromus inermis* at Madison does not cause the usual blotching, but is present only in slender streaks between the principal parallel veins of the leaf blade.

A Ramularia (?) found on *Anemone cylindrica* perhaps is RAMULARIA RANUNCULI Pk. f. ANEMONES. The entire leaf is involved. Conidia are from 10-20 x 3-4$\mu$, arising from a small, compact brownish stroma. I have been unable to compare the conidia with those of other specimens, since in the material available the conidia have fallen away.

A Cercospora on *Oxalis stricta,* collected at Madison August 16, was sent to Professor Chupp. He states that it appears to be CERCOSPORA OXALIDIPHILA Speg. ined. It is present in South America and the West Indies, but has not been reported from the United States before. It seems that Spegazzini did not publish a description, but Professor Chupp has a specimen from Spegazzini's herbarium on Oxalis sp. from Riachuelo, Buenos Aires, Argentina, collected by Spegazzini, Febr. 1880, and listed as No. 962.

CERCOSPORA OXYBAPHI Ell. & Hals. on *Oxybaphus nyctagineus,* collected in October at Madison, is on sharply delimited spots, instead of being effused. It appears that this condition may be connected with the beginning of a perfect stage, for immature perithecium-like bodies are also present on the spots.

Both *Silphium terebinthinaceum* and *Silphium laciniatum* were heavily infected with CERCOSPORA SILPHII Ell. & Ev., in the Arboretum of the University of Wisconsin at Madison. The fungus is represented in the Herbarium by a single previous collection on each host.

Alternaria occurred in definite spots on living leaves of *Phytolacca decandra* at Madison, October 13. As in most other such cases, however, parasitism is doubtful unless proved.

Alternaria has been observed, in a possibly parasitic relationship, on the blighted tips of leaflets of *Petalostemum candidum.* Dane Co., Madison, July 27.

In a previous publication (Trans. Wis. Acad. Sci. *32*: 78, 1940) reference was made to BOTRYTIS sp. on *Ranunculus abortivus.* Similar material on the same host has been collected at Mt. Vernon, Dane Co., by Mr. C. G. Shaw. The specific standing is equally doubtful.

*Vicia villosa* growing in the University Arboretum at Madison was observed in early June to be suffering from a severe blight caused by BOTRYTIS sp. The spore heads are small, usually a short terminal extension of the main stalk, with two equally short side branches, parallel with one another, and departing from the stalk at right angles. The conidia are indeterminate in number, from few to many, globose, smooth, 14-20$\mu$ diam. Conidiophores may be 3- or more septate, up to 350$\mu$ long, with an average width of 10-12$\mu$. The leaf first shows the infection as rounded pale brown arcs extending to the edges of individual leaflets. Later the entire leaflet becomes involved, and finally drops off. The lower portions of the host plants were much more heavily infected than the upper, actively growing parts.

*Aster linariifolius* in the vicinity of Madison is attacked by what seems to be an extremely delicate Gloeosporum or Marsonia. The spots are definite, gray-brown with a yellow border, tending to be circular, but usually impinging upon the margin or the midrib of the narrow leaves. Considerable portions of the leaves often show a purplish discoloration of the areas containing the spots. Repeated attempts to demonstrate attachment of conidia have failed, although all the numerous mounts prepared have shown the crescent-shaped spores, which are from 25-35$\mu$ long by 4-6$\mu$ wide at the point of greatest diam. The smooth, dry, highly cutinized surface of this xerophyte probably does not favor persistence of mycelial structures produced on it.

*Veronica peregrina* has been observed by me on several occasions, and by others, to be infected with a most unusual fungus. The fruits and seeds alone are invaded, for stained permanent sections show that the fungus is not present in the pedicels of the fruits. The many-seeded fruits, and the seeds themselves, become packed with a white felted mycelial mass. This mass consists of large numbers of much branched hyphae, each of which is apparently separate from its neighbors, resembling superficially the young branched mycelium developing from a germinated spore. There is no evidence to show that such is the immediate origin of these hyphae, however. The hyphae are relatively wide with thick, tuberculate walls. Individual cells are not much longer than wide and appear to be multinucleate. The branches do not taper and the terminal cell of each is rounded at its tip. The general effect is one of stiffness and inflexibility. I have not seen fruiting structures of any sort.

A curious fungus occurred in scanty development on *Tephro-*

*sia virginiana* at Madison in September. It might be assigned to Stagonospora, to Septogloeum, or perhaps to the Leptostromataceae, without in any case doing violence. The epiphyllous structures in which the spores are borne are globular to rounded-oblong, with the base sunk in the leaf substratum and the upper portion erumpent. These receptacles are dark, loosely pseudoparenchymatous, and merge into the substratum. The spores are hyaline, short-cylindrical, 1-6-septate, from 10-35 x 7-10$\mu$, with relatively few being produced in a single fruiting structure.

## ADDITIONAL HOSTS

BASIDIOPHORA ENTOSPORA Roze & Cornu on *Aster laevis*. Waukesha Co., Eagleville, September 3.

PLASMOPARA HALSTEDII (Farl.) Berl. & DeToni on *Helianthus rigidus*. Dane Co., Madison, August 10. Seedlings infected. Mature plants, among which the seedlings were interspersed, were not affected.

ERYSIPHE CICHORACEARUM DC. on *Aster oblongifolius*. Sauk Co., Cactus Bluff, September 28. On *Aster pilosus*. Dane Co., Madison, October 7.

ERYSIPHE CICHORACEARUM DC. on *Helianthus occidentalis*. Waukesha Co., Eagleville, August 19.

ROSENSCHELDIA HELIOPSIDIS (Schw.) Theiss. & Syd. on *Aster lucidulus*. Waukesha Co., Eagleville, September 12. On *Aster junciformis*. Walworth Co., East Troy, August 14. Both specimens are sterile.

PHYLLACHORA GRAMINIS (Pers.) Fckl. on *Hordeum jubatum*. Dane Co., Madison, August 30. Determined by Dr. C. R. Orton.

PHYLLACHORA PUNCTA (Schw.) Orton on *Leptoloma cognatum*. Dane Co., Madison, August 24. So far as I am aware, previously reported only on the closely related Panicum. The infection was extensive, involving many plants over a wide area.

PHYLLACHORA PUNCTA (Schw.) Orton on *Panicum implicatum*. Waukesha Co., Eagleville, September 20.

COLEOSPORIUM SOLIDAGINIS (Schw.) Thuem. II on *Aster oblongifolius*. Dane Co,. Madison, October 14. On *Aster oblongi-*

*folius* var. *angustatus.* Columbia Co., Black Hawk's Lookout, near Prairie du Sac, October 10. On *Aster novi-belgii* (cult.). Dane Co., Madison, October 17. II, III on *Aster ericoides,* Dane Co., Madison, October 12.

TRANZSCHELIA PRUNI-SPINOSAE (Pers.) Diet. O on *Hepatica triloba.* Waukesha Co., Eagleville, June 10. The aecia are immature.

PUCCINIA RUBIGO-VERA (DC.) Wint. III on *Bromus latiglumis.* Iron Co., Saxon Falls, August 30, 1931. Collected by Newton Bobb. It may be that *Bromus purgans* should be deleted as a Wisconsin host, since it seems possible that it has been confused with *Bromus latiglumis.*

PUCCINIA HEUCHERAE (Schw.) Diet. on *Heuchera richardsonii* var. *affinis.* Waukesha Co., Eagleville, May 27. Reported for Wisconsin on *Heuchera hispida* which was the name formerly used for *Heuchera richardsonii* var. *grayana* by most authors. It is, however, extremely likely that collections have been made in the past on var. *affinis,* without its being recognized as such, owing to the confusion over the taxonomy of the genus Heuchera.

UROMYCES PUNCTATUS Schroet. II on *Oxytropis chartacea.* Waushara Co., Plainfield, September 15, 1934. Coll. N. C. Fassett. The host is known only from the Waushara Co. station and from southern Bayfield Co.

PUCCINIA ANGUSTATA Pk. I on *Monarda fistulosa.* Dane Co., Madison, June 3. The specimen was submitted to Dr. G. B. Cummins for confirmation of the determination.

PUCCINIA VEXANS Farl. I on *Acerates viridiflora* var. *lanceolata.* Dane Co., Madison. Collected by T. J. Hale in 1860 or 1861. This was found, with aeciospores intact, on a phanerogamic specimen in the University of Wisconsin Herbarium. Trelease reported this on *Acerates longifolia* (*A. floridana*) from LaCrosse in 1883, and Davis collected P. VEXANS on *Acerates lanuginosa* at Prairie du Sac in 1929.

PUCCINIA PHYSALIDIS Pk. on *Physalis heterophylla.* Dane Co., Madison, September 14.

PUCCINIA EXTENSICOLA Plowr. I on *Solidago patula.* Walworth Co., East Troy, July 1.

PUCCINIA ASTERIS Duby on *Aster ericoides.* Walworth Co., Lake Lulu, June 30; Dane Co., Madison, October 12.

PUCCINIA SILPHII Schw. on *Silphium terebinthinaceum.* Waukesha Co., Scuppernong Prairie near Eagle, August 2. Dr. Cummins states that while he has no previous record of P. SILPHII having been collected in the field on this host, infection has nevertheless been successfully produced by inoculating with teliospores from both *Silphium perfoliatum* and *S. integrifolium.*

PHYLLOSTICTA ANEMONICOLA Sacc. & Syd. on *Anemone cylindrica.* Dane Co., Madison, August 16. Great numbers of conidia are produced in the relatively large pycnidia.

SEPTORIA ANDROPOGONIS J. J. Davis on *Sorghastrum nutans.* Dane Co., Madison, September 10. The lesions closely resemble those on the nearly related *Andropogon furcatus.* The spores are of generally similar form, but they are longer, up to 70$\mu$, and mostly show 8 or 9 septations. It is possible that this should have varietal distinction, but it does not seem sufficiently different from S. ANDROPOGONIS to be described as a new species.

SEPTORIA GRAMINUM Desm. on *Panicum praecocius.* Also on *Panicum implicatum.* Dane Co., Madison, August 30. On *Panicum boreale.*. Waukesha Co., Eagleville, September 20.

SEPTORIA CORYLINA Pk. on *Corylus americana.* Dane Co., Madison, October 19.

SEPTORIA DIVARICATA Ell. & Ev. on *Phlox paniculata.* Dane Co., Madison, August 16. Various specimens labelled as this show vast differences in spore length.

SEPTORIA LIATRIDIS Ell. & Davis on *Liatris ligulistylis.* Waukesha Co., Eagleville, July 27. On *Liatris squarrosa* (cult.). This is the smooth form, *Liatris glabrata* of Rydberg. Dane Co., Madison, August 7.

SEPTORIA ASTERICOLA Ell. & Ev. on *Aster pilosus.* Dane Co., Madison, October 1. On basal leaves.

SEPTORIA ATROPURPUREA Pk. has been reported on *Aster puniceus* in Wisconsin. The former *Aster puniceus* var. *lucidulus* is at present considered to be a separate species, so that *Aster lucidulus* must be added to the list of hosts. Southern Wisconsin collections are undoubtedly mostly on *A. lucidulus.*

SEPTORIA SOLIDAGINICOLA Pk. on *Aster paniculatus* var. *simplex.* (*Aster tradescanti* of Gray's Manual). Likewise occurring in the same vicinity on what appears to be a hybrid of *Aster lucidulus* and of *A. paniculatus* var. *simplex.* Dane Co., Madison, August 25.

SEPTORIA SOLIDAGINICOLA Pk. on *Solidago nemoralis.* Dane Co., Madison, August 8.

SEPTORIA CHRYSANTHEMELLA Cav. on *Chrysanthemum leucanthemum* var. *pinnatifidum.* Dane Co., Madison, June 26. Davis reports this as occurring on cultivated *Chrysanthemum* sp. at Racine. The sporules are described as being 42-48 x 1-2$\mu$, which is under the limits of the Saccardian description of 55-65$\mu$. I do not find this specimen in the Herbarium. However, a later specimen from Admiral, Md., determined by Davis, has sporules mostly 60-70$\mu$, or even slightly longer, as does also the Madison specimen.

SEPTORIA LACTUCICOLA Ell. & Mart. an *Lactuca ludoviciana.* Dane Co., Madison, September 10.

LEPTOTHYRIUM DRYINUM Sacc. on *Quercus macrocarpa.* Dane Co., Madison, October 2.

LEPTOTHYRIUM SIMILISPORUM (Ell. & Davis) Davis on *Solidago nemoralis.* Dane Co., Madison, August 17; Waukesha Co., Eagleville, September 6.

ENTOMOSPORIUM (THUEMENII (Cke.) Sacc.) ? on *Crataegus oxyacantha* (cult.) Dane Co., Madison, August 30. On *Crataegus mollis.* Dane Co., Madison, September 10. I am entirely unconvinced that there is any satisfactory morphologic basis for the separation of different species of Entomosporium on Rosaceae.

TITAEOSPORA DETOSPORA (Sacc.) Bubak on *Equisetum kansanum.* Waukesha Co., Eagleville, August 28. Bubak regards the following as synonyms of T. DETOSPORA: SEPTORIA DETOSPORA Sacc., RHABDOSPORA DETOSPORA (Sacc.) Allesch., GLOEOSPORIUM EQUISETI Ell. & Ev., and SEPTOGLOEUM EQUISETI (Ell. & Ev.) Died. Davis records GLOEOSPORIUM EQUISETI on *Equisetum* sp. indet. from Sullivan, Jefferson Co. Davis later noted the erection of Titaeospora by Bubak, but did not alter the Wisconsin record. I agree with Bubak that, on the basis of the generic description of Gloeosporium, this fungus cannot be assigned to that genus, and I think that the establishment of a new genus is probably justified.

COLLETOTRICUM GRAMINICOLUM (Ces.) Wils. on *Paspalum stramineum*. Crawford Co., Prairie du Chien, September 15, 1940. Coll. L. H. Shinners.

COLLETOTRICHUM GRAMINICOLUM (Ces.) Wils. on *Panicum virgatum*. Dane Co., Madison, August 10. This appeared to be lethal.

COLLETOTRICHUM HEPATICAE Pk. on *Hepatica triloba*. Waukesha Co., Eagleville, October 25. Rather doubtfully parasitic.

COLLETOTRICHUM SILPHII J. J. Davis on *Silphium integrifolium*. Dane Co., Madison, August 10. Previously known only on *Silphium perfoliatum* where the lesions are identical with those on *S. integrifolium*.

CYLINDROSPORIUM SHEPHERDIAE Sacc. on *Elaeagnus argentea* (cult.). Dane Co., Madison, October 3.

MONILIA CRATAEGI Died. on *Crataegus mollis*. Dane Co., Madison, May 14. Coll. M. P. Backus. According to Professor Backus this fungus was the cause of a destructive blight of trees of *C. mollis* on the campus of the Agricultural College of the University of Wisconsin.

RAMULARIA GEI (Eliass.) Lindr. on *Geum strictum*. Dane Co., Madison, June 8. I follow Davis in temporarily assigning to this species a form that verges on Cercosporella and which, except for somewhat shorter conidiophores is much like the fungus described by Davis on *Geum* sp. in an earlier publication (Trans. Wis. Acad. Sci. *24*: 276, 1929). Also on *Geum triflorum*. Waukesha Co., Eagleville, August 2. In this collection, by contrast to that on *G. strictum*, the conidia are 22-35 x 3-4$\mu$, mostly uniseptate, occasionally continuous. The tufted conidiophores are stiffly curved, candelabra-like, 10-25 x 3$\mu$.

RAMULARIA ASTERIS (Phil. & Plowr.) Bubak on *Aster ptarmicoides*. Waukesha Co., Eagleville, August 19. On *Aster pilosus*. Dane Co., Madison, October 1.

PIRICULARIA PARASITICA Ell. & Ev. on PHYLLACHORA VULGATA on *Muhlenbergia foliosa.* Dane Co., Madison, August 11.

CERCOSPORELLA DEARNESSII Bubak & Sacc. on *Solidago patula.* Walworth Co., East Troy, August 20. Conidiophores up to 75μ, the conidia to 130μ. Material from Eagleville, Waukesha Co., with shorter conidiophores may represent a bridging form between this and CERCOSPORELLA NIVEA.

CLADOSPORIUM ASTERICOLA J. J. Davis on *Solidago speciosa.* Dane Co., Madison, October 2. Epiphyllous instead of hypophyllous as in the type on *Aster umbellatus.* Davis found this also on *Solidago serotina.*

FUSICLADIUM DEPRESSUM (B. & Br.) Sacc. on *Oxypolis rigidior.* Dane Co., Madison, August 5.

SCOLECOTRICHUM GRAMINIS Fckl. on *Alopecurus carolinianus.* Rock Co., Edgerton, June 7, 1912. Coll. J. Johnson. The host was entered in the Herbarium as *Alopecurus geniculatus* var. *aristulatus* as of Gray's Manual. Recent workers have set out *A. carolinianus* Walt. from *A. geniculatus* var. *aristulatus,* and the latter has in turn been placed under *A. aequalis* Sobol. Thus, *Alopecurus carolinianus* and *A. aequalis* are the Wisconsin Alopecurus hosts for SCOLECOTRICHUM GRAMINIS.

HELMINTHOSPORIUM SATIVUM Pamm., King & Bakke on *Panicum capillare.* Waukesha Co., Eagleville, August 18. Not before reported on Panicum, so far as I am aware.

CERCOSPORA FUSIMACULANS Atk. on *Leptoloma cognatum.* Dane Co., Madison, June 23. Determined by Professor Chupp who states that this is a highly variable species. He regards CERCOSPORA PANICI J. J. Davis as a synonym.

CERCOSPORA FUSIMACULANS Atk. on *Panicum praecocius.* Dane Co., Madison, August 20. On *Panicum scribnerianum.* Dane Co., Madison, June 24. On *Panicum leibergii.* Walworth Co., Lake Lulu, June 30; Waukesha Co., Eagleville, August 21. On *Panicum perlongum.* Walworth Co., Lake Lulu, August 21; Dane Co., Madison, September 11.

CERCOSPORA CYPRIPEDII Ell. & Dearn. on *Cypripedium candidum.* Waukesha Co., Eagleville, September 3.

CERCOSPORA RHOINA Cke. & Ell. on *Rhus vernix.* Jefferson Co., Lake Mills, September 17, 1940.

CERCOSPORA OMPHACODES Ell. & Holw. on *Phlox pilosa.* Dane Co., Madison, June 22. Determined by Professor Chupp.

CERCOSPORA PARVIMACULANS J. J. Davis on *Solidago riddellii.* Dane Co., Madison, August 25. The spots are dark purple, small, and angled. Professor Chupp considers this to be a synonym of CERCOSPORA STOMATICA, described earlier by Davis. There seem to me to be sufficient differences so as to constitute reasonable doubt as to this, so I am provisionally continuing to use the name C. PARVIMACULANS. On *Solidago uliginosa.* Waukesha Co., Eagleville, September 3. On *Solidago rigida.* Walworth Co., Lake Lulu, July 27. The spots on these hosts are mostly somewhat larger than those of most specimens on *Solidago serotina,* the only species on which Davis collected this fungus, but the microscopic characters correspond satisfactorily.

MACROSPORIUM SAPONARIAE Pk. on *Silene stellata.* Waukesha Co., Eagleville, August 19.

## ADDITIONAL SPECIES

APHANOMYCES EUTICHES Dreschsler on *Pisum sativum* caused severe losses to growers throughout the pea canning areas of Wisconsin in 1942.

**Mycosphaerella krigiae** (Ell. & Ev.) n. comb. Ellis and Everhart, in their "North American Pyrenomycetes," p. 280, described *Sphaerella krigiae,* the description being based on immature material of a Mycosphaerella on *Krigia amplexicaulis,* collected by J. J. Davis at Racine, Wis. in June, 1890. At Madison, August 16, 1942, I found *K. amplexicaulis* heavily infected with a Mycosphaerella which, judging from the spots and the fungus itself, is the same thing found by Davis. In the present specimen, however, the uniseptate spores are mature, measuring about 10 x 2.5$\mu$. In other characters the original description seems adequate, except that the spots in my specimen are in general of somewhat greater diameter.

COLEOSPORIUM DELICATULUM (A. & K.) Hedgc. & Long II, III on *Euthamia graminifolia.* Dane Co., Madison, October 13. Det. by G. B. Cummins.

PUCCINIA AMPHIGENA Diet. III on *Calamovilfa longifolia.* Marquette Co., Montello, September 12, 1937. Coll. N. C. Fassett. The host was doubtless introduced from farther west.

Through a misunderstanding, ENTYLOMA ASTER-SERICEANUM Zund., based on material collected in Wisconsin, was listed as ENTYLOMA ASTER-SERICEAE Zund. The description of the species was published in Mycologia *34*: 126, 1942.

PHYLLOSTICTA CHENOPODII-ALBI Siemaszko on *Chenopodium album.* Dane Co., Madison, August 10. Tehon and Daniels (Mycologia *11*: 121, 1927) offer a key to five Phyllostictae occurring on Chenopodia, but do not include P. CHENOPODII-ALBI. They establish a limit of 70-80$\mu$ diam. for the pycnidia of PHYLLOSTICTA AMBROSIOIDES Thum., although no size limits are cited in the Saccardian description. Siemaszko specifies a diameter of 140-200$\mu$ for the pycnidia of P. CHENOPODII-ALBI, which corresponds to the material I have collected. It seems that despite pycnidial size P. CHENOPODII-ALBI may possibly be a synonym for P. AMBROSIOIDES. Neither has been previously reported from Wisconsin.

PHYLLOSTICTA CORNICOLA (DC.) Rabh. on *Cornus alternifolia.* Walworth Co., East Troy, August 20. The conidia are slightly smaller than is indicated in the description. N. A. F. 2833, which is labelled PHYLLOSTICTA CORNICOLA, proved to be *Septoria cornicola* Desm.

PHYLLOSTICTA ANTENNARIAE Ell. & Ev. on *Antennaria fallax.* Waukesha Co., Eagleville, June 16. The original description is meager, but this material matches it in all points specified. There were no specimens in the Herbarium for comparison.

ASCOCHYTA VERBENAE Siemaszko on *Verbena stricta.* Dane Co., Madison, July 7. The spots are very small, arid, with a narrow, dark purple border. Conidia are 6-7 x 3$\mu$, while the pycnidia are about 110$\mu$ diam., more or less.

DIPLODIA ZEAE (Schw.) Lev. on *Zea mays.* Dane Co., Madison, August 9. Coll. & det. M. P. Backus. This common fungus, causing the dry rot of ear corn, is not mentioned by Davis and is here included for the sake of completeness.

HENDERSONIA CALAMOVILFAE Petr. on *Calamovilfa longifolia*. Marquette Co., Montello, September 12, 1937. Coll. N. C. Fassett. Associated with PUCCINIA AMPHIGENA Diet. on yellowed foliage of *C. longifolia*. HENDERSONIA CALAMOVILFAE is a striking and well-marked species, but doubtfully parasitic. It was erected on material collected by Brenckle in 1923 at Kulm, North Dakota.

Davis in July 1929 found SEPTORIA sp. on the dead stems of *Linaria canadensis* (Trans. Wis. Acad. Sci. *26*: 260, 1931). The collection was made at Arena, Iowa Co. In 1938 I collected similar material in great abundance at the same station in June. It seemed at the time that, despite Davis' suggestion that his specimen was probably abnormal in development, such was not the case. (Greene, Trans. Wis. Acad. Sci. *32*: 77, 1940). In June 1942, a late season, the same Septoria was found on the still green stems and leaves of *Linaria canadensis*, thus behaving as a parasite. The third collection was made in the University of Wisconsin Arboretum at Madison, Dane Co. This fungus is evidently a well-marked and constant form and is therefore described as a new species:

SEPTORIA LINARIAE n. sp.

Pycnidia black, globose, firm, pseudoparenchymatous, ostiolate, rostrate, deeply seated in the host tissue, gregarious on pale, indeterminate spots on stems and leaves, 80-125$\mu$ diam.; beaks protruding, 35-60$\mu$ wide, 35-45$\mu$ long; conidia numerous, hyaline, lax, filiform, continuous, 30-50 x 1$\mu$; conidiophores short, almost obsolete.

On stems and leaves of *Linaria canadensis* (L.) Dumont., Madison, Wisconsin, U. S. A., June 1942.

SEPTORIA LINARIAE sp. nov.

Pycnidiis nigris, globosis, firmis, contextu pseudoparenchymatico, poro pertusis, rostratis, immersis, gregariis, in maculis pallidis indeterminatis in caulibus et foliis, 80-125$\mu$ diam.; ostiolis prominentibus, 35-60$\mu$ latis, 35-45$\mu$ longis; conidiis numerosis, hyalinis, laxis, filiformibus, non septatis, 30-50 x 1$\mu$; conidiophoris brevibus, prope absentibus.

In caulibus et foliis *Linariae canadensis* (L.) Dumont., Madison, Wisconsin, U. S. A.

SEPTORIA VALERIANAE Sacc. & Fautr. on *Valeriana ciliata.* Dane Co., Madison, July 6. The pycnidia are amphigenous. Although the spores are longer, on the average, than specified in the description, running from 25-50$\mu$, mostly 35-45 x 1.5, it is well known that great differences in spore length may sometimes exist within the same species.

SEPTORIA LEPACHYDIS Ell. & Ev. on *Lepachys pinnata.* Waukesha Co., Eagle, August 19. Also found on *Echinacea purpurea* (cult.) (*Brauneria purpurea* of Gray's Manual). Dane Co., Madison, July 7. On the latter host the slender sporules are up to 25$\mu$ long.

LEPTOTHYRIUM PUNCTIFORME B. & C. on *Erigeron annuus.* Dane Co., Madison, June 5. Bubak at one time set out LEPTOTHYRIUM DEARNESSII on the same host, but later reached the conclusion that the two fungi are identical (Hedwigia *58*:26, 1917).

KABATIELLA CAULIVORA (Kirchn.) Karak. on *Trifolium pratense.* Dane Co., Madison, August 15, 1941. Coll. J. L. Allison and D. W. Chamberlain.

BOTRYTIS CINEREA Pers. has been found as a weak parasite on pods of *Phaseolus aureus* (Mung bean). Dane Co., Black Earth, September 20. Coll. & det. M. P. Backus.

SPHACELOMA PLANTAGINIS Jenkins & Bitancourt on *Plantago rugelii.* Dane Co., Madison, August. Coll. A. S. Costa. The writer is indebted to Dr. Anna E. Jenkins of the Bureau of Plant Industry for a specimen of this newly discovered species.

CLADOSPORIUM FASCICULATUM Cda. on *Evonymus atropurpureus.* Waukesha Co., Eagleville, August 20. Under a hand lens the tufted conidiophores resemble those of a Cercospora. The fascicles are epiphyllous, on long, narrow, pale brown marginal spots. The inner border of the spots is reddish purple.

CERCOSPORA "GRAPHIOIDES" Ell. occurs on *Prunus serotina* in Wisconsin. This is not CERCOSPORA CIRCUMSCISSA Sacc., from which it differs in having conidia often wider than 5$\mu$, and the conidiophores strongly fascicled, sometimes almost coremoid. The validity of the Ellis name is questionable, for while he issued a printed label (N. A. F. No. 646), there is no diagnosis on the label, and according to Professor Chupp, there is no printed description elsewhere. Professor Chupp informs me that to the best of his knowledge all collections on *Prunus serotina* are CERCOSPORA GRAPHIOIDES Ell.

**Cercospora caracallae** (Speg.) n. comb. on *Phaseolus aureus* (cult.) Dane Co., Black Earth, September 20. (*Cercosporina caracallae* Speg., Anales del Museo Nacional de Buenos Aires *20*: 425, 1910). Coll. M. P. Backus. Determined by Professor Chupp who states that this species heretofore has not been reported from North America. He has received specimens from Argentina, Brazil, and Puerto Rico.

CERCOSPORA BACILLIGERA (B. & Br.) Fres. on *Rhamnus frangula* (cult.). Waukesha Co., Eagleville, August 18. Determined by Professor Chupp who states that this species differs from the others on Rhamnus in its hyaline conidia and short, delicate conidiophores.

CERCOSPORA MALVARUM Sacc. on *Malva rotundifolia.* Dane Co., Madison, August 10. Determined by Professor Chupp.

A species of Cercospora found on *Gerardia grandiflora* (*Aureolaria grandiflora* var. *pulchra* Pennell) at Madison appears to fit no form previously described on the Scrophulariaceae. In cooperation with Professor Charles Chupp this species is here described as CERCOSPORA MADISONENSIS Chupp & Greene:

CERCOSPORA MADISONENSIS n. sp.

Leaf spots circular, 0.5-2 mm. diam., white center, reddish to purplish border, fruiting amphigenous; fascicles dense, short on upper surface, often non-fasciculate, long on lower surface; conidiophores pale to medium brown, paler and more narrow toward the tip, multiseptate, branched on lower leaf surface, tortuous or 1-3-geniculate, tip rounded to subtruncate, 4-6 x 20-200$\mu$; conidia hyaline, acicular to obclavate, straight to slightly curved, indistinctly multiseptate, base truncate to subtruncate, tip subacute, 2-3.5 x 20-70$\mu$.

On leaves of *Gerardia grandiflora.* Madison, Wisconsin, U. S. A. September 14, 1942.

Specimens from the type collection are deposited in the Herbarium of the University of Wisconsin and in the Herbarium of the Department of Plant Pathology, Cornell University, Ithaca, New York.

CERCOSPORA MADISONENSIS sp. nov.

Maculis rotundatis, 0.5-2 mm. diam., centris albis, marginibus roseis vel purpureis, conidiophoris amphigenis, fasciculis densis, brevibus in superioribus superficiebus, saepe non-fasciculatis, longis in inferioribus superficiebus; conidiophoris pallidis vel brunneolis, pallidioribus et angustioribus ad apicibus, multiseptatis, ramosis in inferioribus superficiebus, contortis vel 1-3-geniculatis, apicibus rotundatis vel subtruncatis, 4-6 x 20-200$\mu$; conidiis hyalinis, acicularibus vel obclavatis, rectis vel leviter curvatis, indistinctatis multiseptatis, basibus truncatis vel subtruncatis, apicibus subacutis, 2-3.5 x 20-70$\mu$.
In foliis *Gerardiae grandiflorae.* Madison, Wisconsin, U. S. A.

CERCOSPORA BIDENTIS Tharp on *Bidens cernua.* Dane Co., Madison, August 11. Determined by Professor Chupp who tells me that the Wisconsin material on this host which formerly was referred to CERCOSPORA MEGALOPTAMICA Speg. should be placed under C. BIDENTIS.

CERCOSPORA TRAGOPOGONIS Ell. & Ev. on *Tragopogon pratensis.* Dane Co., Madison, August 17. This species is described in Bull. Torr. Bot. Club *24*: 474, 1897. The conidiophores in my specimen are somewhat longer than the 20-30$\mu$ of the description, being up to 45$\mu$, but in other characters there is close correspondence.

CERCOSPORA LONGISSIMA Sacc. on *Lactuca scariola.* Dane Co., Madison, August 30. Determined by Professor Chupp.

CERCOSPORA ARCTI-AMBROSIAE Hals. on *Arctium minus.* Dane Co., Madison. September 14.

STEMPHYLIUM SARCINAEFORME (Cav.) Wilt. MACROSPORIUM SARCINAEFORME (Cav.) on *Trifolium pratense.* Dane Co., Madison, October 30, 1940. Coll. J. L. Allison. Said to be common on this host in Wisconsin.

FUSARIUM PTERIDIS Ell. & Ev. on PHYLLACHORA GRAMINIS on *Hordeum jubatum.* Dane Co., Madison, August 30. This has also been called SEPTOGLOEUM PTERIDIS (Ell. & Ev.) Wr. I have examined the Ellis and Everhart material (N. A. F. 2982) which is on CRYPTOMYCES PTERIDIS and corresponds well with my own collection. Neither appears to me to be Septogloeum.

SCLEROTIUM MENDAX Sacc. on *Solidago altissima.* Dane Co., Madison, August 10; September 13. Saccardo's description of this is based on a specimen from New York State, so it seems probable that the Wisconsin collection is the same thing, although no specimens were available for comparison.

Through the courtesy of Professor J. L. Allison and Mr. D. W. Chamberlain of the Department of Plant Pathology of the University of Wisconsin the following list of fungi parasitic on grasses in Wisconsin has been made available. Although these fungi have been, or will be, reported elsewhere, they are included here in order to make these notes, together with those of the late J. J. Davis, as complete an account as possible of all fungi known to be parasitic on plants in Wisconsin:

## ADDITIONAL HOSTS

COLLETOTRICHUM GRAMINICOLUM (Ces.) Wils. on *Sorghum vulgare* var. *sudanense.*

SCOLECOTRICHUM GRAMINIS Fckl. on *Festuca rubra.*

CERCOSPORA FUSIMACULANS Atk. on *Panicum virgatum.*

UROCYSTIS AGROPYRI (Preuss) Schroet. on *Poa pratensis.* On *Agropyron repens.* On *Hordeum jubatum.*

PUCCINIA GRAMINIS Pers. on *Poa compressa.* On *Agropyron smithii.*

## ADDITIONAL SPECIES

SELENOPHOMA BROMIGENA (Sacc.) Sprague & Johnson on *Bromus inermis.*

STAGONOSPORA BROMI Smith & Ramsb. on *Bromus inermis.*

SEPTORIA ELYMI Ell. & Ev. on *Elymus canadensis.*

SPOROTRICHUM POAE Pk. on *Poa pratensis.*

HELMINTHOSPORIUM TURCICUM Pass. on *Sorghum vulgare* var. *sudanense.*

HELMINTHOSPORIUM RAVENELII M. A. Curtis on *Sporobolus neglectus.*

HELMINTHOSPORIUM VAGANS Drechsler on *Poa pratensis.*

HELMINTHOSPORIUM BROMI Died. on *Bromus inermis.*

USTILAGO BULLATA Berk. on *Bromus marginatus.*

Specimens of most of these have been placed in the University Herbarium.

# ASCOCHYTA MELILOTI (TREL.) DAVIS AS THE CONIDIAL STAGE OF *MYCOSPHAERELLA LETHALIS* STONE

FRED REUEL JONES[1]

Stone in 1912 published an excellent account of the life history of *Mycosphaerella lethalis*, sometimes called the black stem fungus of sweetclover. The conidial stage of this fungus is properly an *Ascochyta*, and it was identified for Stone by Bartholomew as *A. lethalis* Ell. and Barth. (3) This identification which was probably entirely justified at that time has become untenable with later information. First, *A. lethalis* is properly a synonym of *A. caulicola* Laubert (2) described a few months earlier. This opinion is supported by several mycologists who have compared the type collection of *A. caulicola* issued as No. 37 in the Mycotheca germanica by Sydow, and the type of *A. lethalis*, No. 1808 in Ellis and Everhart's Fungi Columbiani. Second, *A. caulicola* is not the conidial stage of *Mycosphaerella lethalis*, but a distinct species without a known ascigerous stage, as has been stated by the author previously (1). However, *A. caulicola* is not clearly distinguishable from the conidial stage of *M. lethalis* by usual mycological characters, but it is easily distinguished in culture and usually by its pathological effects upon the host.

When the synonomy stated above has been made, it becomes necessary to revise the description of the conidial stage of *Mycosphaerella lethalis* and to provide a name for it. In doing this it will be convenient to find a previous name properly applied and a description already written. The name *Ascochyta meliloti* (Trel.) Davis has been suggested to the writer by J. A. Stevenson as possibly fulfilling requirements. The original collection of this species has been examined through the courtesy of the Missouri Botanic Garden. This collection of the vigorous top of

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a young shoot is much discolored as though it had been kept for sometime after collection in a moist chamber to stimulate the fruiting of the fungus. Thus the pathological conditions which might indicate the species present are obliterated. With a specimen in this poor condition it does not appear that an incontestable assignment of the abundant fungus present can be made to either species under consideration—and no other species are known to be admissible for consideration; but after comparing it with many collections of both species made over several years the writer inclines strongly to the opinion that it is the conidial stage of *Mycosphaerella lethalis*. While the abundant fruiting found in this specimen is unusual on young stems, it might have been induced by incubation, and, in fact, the writer has a similar fruiting specimen of this fungus from the field collected on very susceptible *Melilotus dentata*. Thus the use of this name for the conidial stage of *M. lethalis* is suggested, with the description amended to read as follows.

*Mycosphaerella lethalis*, st. con. = *Ascochyta meliloti* (Trel.) Davis. In foliis, maculis orbicularibus, zonatis, brunneis, pycnidiis saepe obscuris; in stipulis, pycnidiis paucis; in caulibus, maculis elongatis, saepe confluentibus, atropurpureis, brunneis aut carbonaceis, rare pallidis; pycnidiis saepe paucis aut numerosis in caulibus vetustis; pycnidiis globosis; prominulis, ostiolatis, 100-150$\mu$; conidiis hyalinis, oblongatis, vel leniter curvis, plerumque uniseptatis, septo in multis infra medium, 5-6 x 13-20$\mu$, plerumque 15-18$\mu$.

## Literature Cited

1. Jones, Fred Reuel
1938. A seed-borne disease of sweetclover. Phytopath. 28: 661-662.

2. Laubert, R.
1903. Ascochyta caulicola. Ein neuer krankheitserreger des steinklees. Arb. Biol. Abt. f. Land u. Forstw. 3: 441-443, illus.

3. Stone, R. E.
1912. The life history of ascochyta on some leguminous plants. Ann. Myc. 10: 564-592, illus.

# FLOWERING PLANTS AND FERNS OF VILAS COUNTY, WISCONSIN*

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The plants listed in this paper were collected during "Spare" hours and days between June 29 and Sept. 3, 1940 while the author was studying bogs, lakes, and forest primeval in the Trout Lake, Vilas County, neighborhood as member of the Geological and Natural History Survey group during the summer of 1940. Conditions under which the plants were collected necessitated limiting the area studied to a few miles adjacent to Trout Lake, and seasonally to the summer aspect. The list is, therefore, incomplete as far as the total plants found in the large county are concerned. The 300 species represent 71 families. Compositae and Gramineae have the highest number of species, with Rosaceae and Cyperaceae next in numerical importance. A specimen of each plant listed has been deposited with the herbaria of Wisconsin University and Butler University of Indianapolis.

While the list is not exhaustive it constitutes, perhaps, a fair representation of the most common plants in the immediate environment of Trout Lake, and could form the nucleus for additional systematic collections in this large, and interesting county of northern Wisconsin.

I am indebted to Dr. Ray C. Friesner of Butler University for determining and checking about one-third of the total collection, especially the ferns and goldenrods; to Mr. Chas. M. Ek, of Kokomo, Indiana for determining all Cyperaceae and Juncus; to Mrs. Agnes Chase of the U. S. National Museum for checking 17 species of grasses; to Dr. Norman C. Fassett of Wisconsin University for identification of Isoetes and Sparganium.

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* This is contribution 135 from the botanical laboratories of Butler University, Indianapolis, Indiana, and Notes and Reports 112 from the Limnological Laboratory of the Wisconsin Geological and Natural History Survey, University of Wisconsin.

For grasses the nomenclature is that of Hitchcock's Manual of the Grasses of the United States, 1935; for the aquatic and some of the shore plants that of Fassett's Manual of Aquatic Plants, 1940; for all other plants Deam's Flora of Indiana, 1940, Gray's Manual of Botany, 7th edition, and various recent publications of nomenclatorial changes. The figures refer to serial collection numbers of the author. A specimen of each plant listed is deposited with the herbaria at the University of Wisconsin and at Butler University, Indianapolis, Indiana. The family names follow alphabetically, and species under each family are, likewise, alphabetically arranged. Starred species have been reported previously for Vilas County by Dr. N. C. Fassett and co-workers in the Transactions of the Wisconsin Academy of Science, Arts and Letters.

Aceraceae: *Acer rubrum* L., 8505. *A. saccharum* Marsh, 8524. **A. spicatum* Lam., 8475.

Aizoaceae: *Mollugo verticillata* L., 8661.

Anacardiaceae: *Rhus typhina* L., 8684.

Apocynaceae: *Apocynum androsaemifolium* L., 8548, 8764.

Aquifoliaceae: *Ilex verticillata* (L.) Gray, 8640. *Nemopanthus mucronata* (L.) Trel., 8631.

Araceae: **Calla palustris* L., 8583.

Araliaceae: *Aralia nudicaulis* L., 8635. *A. racemosa* L., 8703.

Asclepiadaceae: *Asclepias phytolaccoides* Pursh., 8572.

Balsaminaceae: *Impatiens biflora* Walt., 8715.

Betulaceae: *Alnus incana* Moench, 8535. *Betula lutea* Michx., 8599, 8600. *B. papyrifera* Marsh, 8507. *B. pumila* L., 8498. *Corylus americana* Walt., 8644. **C. cornuta* Marsh., 8502. *Ostyra virginiana* (Mill.) K. Koch, 8525.

Campanulaceae: *Campanula rotundifolia* var. *intercedens* (Witasek.) Farw., 8540. **C. uliginosa* Rhyd., 8622, 8638.

Caprifoliaceae: **Diervilla lonicera* Mill., 8433. **Linnaea borealis* var. *americana* (Forbes) Rehder, 8415. **Lonicera canadensis* Marsh, 8652. *Viburnum acerifolium* L., 8526.

Caryophyllaceae: *Lychnis alba* Mill., 8479. *Stellaria graminea* L., 8411. *S. longefolia* Muhl., 8629 (a), 8608.

Chenopodiaceae: *Chenopodium capitatum* (L.) Asch., 8658.

Compositae: *Achillea millefolium* L., 8523. *Anaphalis margaritaceae* (L.) B. & H., 8659. *Antennaria neodioica* Greene,

8464. *Artemisia caudata* Michx., 8709. *Aster macrophyllus* L., 8734. *A. puniceus* L., 8725. *A. sagittifolius* Wedemeyer, 8728. *A. umbellatus* Mill., 8671. *Chrysanthemum leucanthemum* var. *pinnatifidum* Lecoq. & Lamotte, 8420. *Cirsium arvense* (L.) Scop., 8587. *Erechtites hieracifolia* (L.) Raf., 8724. *Erigeron canadensis* L., 8660. *E. ramosus* (Walt.) BSP., 8641. *Eupatorium maculatum* L., 8707. *Gnaphalium obtusifolim* L., 8732. *Helianthus giganteus* L., 8664. *Heliopsis scabra* Dunal., 8590. *Hieracium aurantiacum* L., 8428. *H. canadense* Michx., 8727. *H. floribundum* Wimm. & Grab., 8567. *H. scabrum* Michx., 8700. *Krigia biflora* (Walt.) Blake, 8539. *Prenathes alba* L., 8736. *Rudbeckia hirta* L., 8616. *Senecio plattensis* Nutt., 8463. *Solidago canadensis* var. *gilvocanescens* Rydb., 8669. *S. gigantea* Ait., 8735. *S. gigantea* var. *leiophylla* Fern., 8670. *S. graminifolia* (L.) Salisb., 8662. *S. hispida* Muhl., 8733. *S. juncea* Ait., 8673. *S. nemoralis* Ait., 8710. *S. uniligulata* (DC.) Porter, 8722, 8737. *Tanacetum vulgare* L., 8676.

Convolvulaceae: **Convolvulus spithamaeus* L., 8457.

Cornaceae: **Cornus canadensis* L., 8425, 8650. **C. rugosa* Lam., 8503.

Cruciferae: *Arabis lyrata* L., 8478.

Cyperaceae: *Carex aenea* Fern., 8451, 8687. *C. arctata* Boott., 8436, 8576. *C. comosa* Boott., 8585. *C. communis* Bailey, 8467. *C. crawfordii* Fern., 8530. *C. foenea* Willd., 8509. *C. intumescens* Rudg., 8440. *C. laxiflora* Lam., 8500. *C. pauciflora* Lightf., 8493. *C. paupercula* Michx., 8536. *C. pennsylvanica* Lam., 8417. *C. rostrata* Stokes, 8559. *C. seorsa* E. C. Howe, 8430. *C. substricta* (Kükenth) Mack., 8570. *C. trisperma* Dewey, 8431, 8568. *C. Tuckermani* Dewey, 8552. *Dulichium arundinaceum* (L.) Britt., 8743. *Eriophorum angustifolium* Roth., 8499. *E. gracile* Roth., 8497. *E. virginicum* L., 8746. *Scirpus atrovirens* Muhl., 8569. *S. cyperinus* (L.) Kunth., 8720.

Droseraceae: **Drosera linearis* Goldie, 8484. **D. rotundifolia* L., 8483.

Elatinaceae: **Elatine minima* (Nutt.) Fisch. & Meyer, 9122.

Equisetaceae: *Equisetum pratense* Ehrh., 8456. *E. sylvaticum* var. *pauciramosum* Milde, 8441.

Ericaceae: **Kalmia polifolia* Wang. 8756. **Arctostaphylos uva* *ursi* var. *coactyllis* L. Speng., 8468. *Chamaedaphne calyculata* (L.) Moench, 8533. **Epigaea repens* L., 8434, 9130. **Gaultheria procumbens* L., 8532. **Ledum groenlandicum* Oeder, 8432. *Moneses uniflora* (L.) Gray, 8517. **Monotropa uniflora* L., 8691. **Pyrola asarifolia* var. *incarnata* (Fisch.) Fern., 8465. **P. secunda* L., 8637. **P. virens* Schweigg, 8414. **Vaccinium angustifolium* Ait., 8647. **V. oxycoccus* L. 8429.

Eriocaulaceae: **Eriocaulon septangulare* With., 9112.

Fagaceae: *Quercus borealis* var. *maxima* (Marsh) Ashe, 8504.

Gentianaceae: *Gentiana andrewsii* Griseb., 8729. *Menyanthes trifoliata* var. *minor* Raf., 8486.

Gramineae: *Agropyron repens* (L.) Beauv., 8566. *A. subsecundum* (Link) Hitch., 8663. *Andropogon furcatus* Muhl., 8674. *Agrostis alba* L., 8554, 8577. *A. hiemalis* (Walt.) BSP., 8512. *A. perennans* (Walt.) Tuckerm., 8740. *Brachyelytrum erectum* (Screb.) Beauv., 8575, 8589. *Bromus ciliatus* L., 8731. *B. inermis* Leyss., 8765. *B. kalmii* A. Gray, 8558, 8646, 8495. *Calamagrostis canadensis* (Michx.) Beauv., 8529, 8603. *Cinna latifolia* (Trev.) Griseb., 8607. *Dactylis glomerata* L., 8481. *Danthonia spicata* (L.) Beauv., 8514. *Echinochloa crusgalli* (L.) Beauv., 8668. *Elymus canadensis* L., 8665. *Eragrostis pectinacea* (Michx.) Nees, 8739. *Festuca ovina* L., 8480. *F. rubra* L., 8490. *Glyceria canadensis* (Michx.) Trin., 8534, 8648. *G. grandis* S. Wats., 8557. *G. striata* (Lam.) Hitchc., 8551, 8620. *Milium effusum* L., 8594. *Muhlenbergia foliosa* (Roem. and Schult.) Trin., 8730. *M. racemosa* (Michx.) BSP., 9114. *M. sylvatica* Torr., 8717. *M. uniflora* (Muhl.) Fern., 9115. *Oryzopsis asperifolia* Michx., 8574, 8409. *O. pungens* (Torr.) Hitchc., 8416. *Panicum capillare* L., 8753. *P. depauperatum* Muhl., 8422, 8460, 8520. *P. huachucae* Ashe, 8423. *P. huachucae* var. *fasciculatum* (Torr.) Hubb., 8458. *P. linearifolium* Scribn. 8421, 8496, 8515, 8538. *P. Werneri* Scribn., 8444. *P. xanthophysum* A. Gray, 8424. *Phleum pratense* L., 8508. *Poa annua* L., 8418. *P. compressa* L., 8513. *P. palustris* L., 8410, 8489, 8754. *P. pratensis* L., 8461. *P. saltuensis* Fern. & Wieg., 8442, 8426, 8413, 8438, 8439. *Schizachne purpurascens* (Torr.) Swallen, 8412. *Setaria lutescens* (Weigel) F. T. Hubb., 8667.

Hydrocharitaceae: **Anacharis canadensis* (Michx.) Planch., 8699. **Vallisneria americana* Michx., 8694.
Iridaceae: *Iris versicolor* L. 8445.
Isoetaceae: *Isoetes macrospora* Dur., 9125.
Juncaceae: *Juncus macer* S. F. Gray, 8761. **J. pelocarpus* Mey, 9118. *J. pelocarpus* forma *submersus* Fassett, 9118 (a).
Labiatae: *Lycopus americanus* Muhl., 8711. *L. uniflorus* Michx., 8741. *Mentha arvensis* var. *canadensis* (L.) Briquet, 8627, 8712. *Mimulus glabratus* var. *Michiganensis* (Pen.) Fassett, 8611. *Monarda clinopodia* L., 8675. *Prunella vulgaris* L., 8546, 8761. *Scutellaria galericulata* L., 8581. *S. lateriflora* L., 8718, 8745. *Stachys palustris* L., 8588.
Leguminosae: *Trifolium hybridum* L., 8571. *T. repens* L., 8519.
Liliaceae: *Clintonia borealis* (Ait.) Raf., 8469. *Maianthemum canadense* Desf., 8408 (b). *M. canadense* var. *interius* Fern., 8408 (a). *Smilacina trifolia* (L.) Desf., 8488. *Trillium erectum* L., 8624. *Uvularia sessilifolia* L., 8685.
Lobeliaceae: **Lobelia Dortmanna* L., 9123.
Lycopodiaceae: *Lycopodium annotinum* L., 8721, 8744, 8747. **L. clavatum* L., 8537, 8686. **L. inundatum* L., 9107. **L. obscurum* var. *dendroideum* (Michx.) D. C. Eaton 8471, 8748.
Lythraceae: *Decodon verticillatus* (L.) Ell., 8751.
Myriaceae: **Comptonia peregrina* (L.) Coulter 8506. **Myrica gale* L., 8642.
Najadaceae: *Najas flexilis* (Willd.) Rost. & Schmidt, 8695. *Potamogeton gramineus* var. *graminefolius*, forma *myriophyllus* (Robbins) House, 8677. *P. amplifolius* Tuck., 8696. *P. Richardsonii* (Benn.) Rydb., 8693. *P. Robbinsii* Oakes, 8697. *P. zosteriformis* Fern., 8698.
Nymphaeaceae: *Nymphaea tuberosa* Paine, 8657. *Nuphar variegatum* Engelm., 8678.
Onagraceae: *Circaea alpina* L., 8613. *Epilobium angustifolium* L., 8553. *E. glandulosum* var. *adenocaulon* (Houssk.) Fern., 8630. *Oenothera pycnocarpa* Atk. & Bartl., 8702.
Ophioglossaceae: *Botrychium virginianum* (L.) Sw., 8609.
Osmundaceae: *Osmunda cinnamomea* L., 8449. *O. claytoniana* L., 8618. *O. regalis* L., 8454.
Orchidacae: *Calopogon pulchellus* (Salis.) R. Br., 8491. *Corallorhiza maculata* Raf., 8474, 8541. *Cypripedium acaule* Ait.,

8487. *Habenaria hyperborea* (L.) R. Br., 8610, 8690. *Orchis rotundifolia* Banks, 8614.

Oxalidaceae: *Oxalis montana* Raf., 8621.

Pinaceae: *Abies balsamea* (L.) Mill., 8443. *Larix laricina* (DuRoi) Koch, 9128. *Picea*, 9129. *P. glauca voss mariana* (Mill.) BSP., 9127. *Pinus banksiana* Lam., 8578. *P. resinosa* Ait. 8446. *P. strobus* L., 8511. *Thuja occidentalis* L., 8482. *Tsuga canadensis* (L.) Carr., 9126.

Polygonaceae: *Polygonum convolvulus* L., 8634. **P. natans* A. Eaton, 8680. *P. scabrum* Moench, 8713.

Polypodiaceae: *Athyrium angustum* (Willd.) Presl., 8477, 8605, 8619. **Dryopteris disjuncta* (Rupr.) Morton, 8452. **D. intermedia* (Muhl.) Underw., 8453, 8476, 8597. **D. phegopteris* (L.) C. Chr., 8623. *D. spinulosa* (Mueller) Watt., 8450. *Onoclea sensibilis* L., 8580. **Pteridium aquilinum* var. *latiusculum* (Desf.) Hieronymus, 8501.

Pontederiaceae: **Pontederia cordata* forma *latifolia* (Farw.) House, 9108.

Primulaceae: *Lysimachia quadrifolia* L., 8543. *L. terrestris* (L.) BSP., 8763. *L. thyrsiflora* L., 8591. *Trientalis borealis* Raf., 8448.

Ranunculaceae: **Actaea pachypoda* Ell., 8752. *Anemone quinquefolia* var. *interior* Fern. & Gris., 8466. **Aquilegia canadensis* L., 8419. *Caltha palustris* L., 8625. **Coptis groenlandica* (Oeder) Fern., 8447. *Ranunculus acris* L., 8617. *R. pennsylvanicus* L. f., 8602. *R. reptans* var. *ovalis* (Bigel) T. & G., 9110.

Rosaceae: *Agrimonia gryposepala* Wallr., 8672. *A. striata* Michx., 8706. *Amelanchier canadensis* (L.) Medic., 8649. *A. humilis* Wieg., 8689. *Aronia arbutifolia* (L.) Ell., 8582. *A. melanocarpa* (Michx.) Ell., 9111. *Fragaria vesca* var. *americana* Porter, 8615. *Physocarpus opulifolius* (L.) Maxim, 8714. *Potentilla palustris* (L.) Scop., 8565. *Prunus pennsylvanica* L. f., 8510. *P. pumila* L., 8628. *P. serotina* Ehrh., 8542. *P. virginiana* L., 8518. *Rubus allegheniensis* Porter, 8760. *R. idaeus* L., 8544. *R. parviflorus* Nutt, 8573. *R. pubescens* Raf., 8629. *Sorbus americana* Marsh., 8592. *Spiraea alba* DuRoi, 8672(a), 8679. *Waldsteinia fragarioides* (Michx.) Trattinick, 8407.

Rubiaceae: *Galium tinctorium* L., 8528. *G. triflorum* Michx., 8470, 8473. *Mitchella repens* L., 8579, 8596.

Salicaceae: *Populus grandidentata* Michx., 8682. *P. tremuloides* Michx., 8522. *Salix bebbiana* Sarg., 8521, 8688.

Santalaceae: *Comandra Richardsiana* Fern., 8437.

Sarraceniaceae: *Sarracenia purpurea* L., 8492.

Saxifragaceae: *Ribes americanum* Mill., 8626. **Saxifraga pennsylvanica* L., 8636.

Scrophulariaceae: *Chelone glabra* L., 8716. *Gerardia paupercula* var. *borealis* Pennell, 1917. *Gratiola lutea* Raf., 9116. *G. lutea* forma *pusilla* (Fassett) Pennell, 8704. *Linaria vulgaris* Hill, 8593. *Melampyrum lineare* var. *typicum* Lam., 8531. *Verbascum thapsus* L., 8651. *Veronica americana* Schwein, 8612.

Sparganiaceae: **Sparganium angustifolium* Michx., 9121.

Taxaceae: *Taxus canadensis* Marsh, 8598.

Thymelaceae: *Dirca palustris* L., 8595.

Tiliaceae: *Tilia americana* L., 8681.

Typhaceae: *Typha latifolia* L., 8584.

Umbelliferae: *Cicuta bulbifera* L., 8726. *Heracleum lanatum* Michx., 8705.

Urticaceae: *Ulmus americana* L. 8749.

Verbeneaceae: *Verbena hastata* L., 8750.

Violaceae: *Viola pubescens* var. *Peckii* House, 8472. *V. rostrata* Pursh., 8435.

# A POLLEN STUDY OF FOUR BOGS ALONG THE SOUTHERN BORDER OF VILAS COUNTY, WISCONSIN*

J. E. POTZGER AND C. O. KELLER

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Two previous papers on pollen studies of bogs in northern Wisconsin, one on a series along the Michigan-Wisconsin state line, on the Gillen Nature Reserve, by Potzger (1942), the other by Potzger-Richards (1942) reporting on five bogs from the neighborhood of Trout Lake, have shown development of the well known "dual" type of forest association in the lake forest. The one association is dominated by Pinus and the other by northern hardwoods. These two studies definitely indicate that during comparatively recent times the climate of upper Wisconsin moderated sufficiently to enable northern hardwoods to invade and partly replace the long-standing complete dominance by Pinus. Apparently Pinus is now post climax which maintains itself indefinitely in the less favorable sandy soils.

The present study is a part of a line transect investigation westward from Woodruff, along highway 70. The specific aim was to see whether succession of forests in northern Wisconsin moved uniformly the same over a broad belt, even westward of the lakes area, or if the southern edge of the region with abundant small lakes (Vilas County), and westward the prairie exerted some modifying influence on the succession of forests, to cause a variation from the succession operating in the county itself. The bogs of this study represent a linear east-west distance of approximately 25 miles, extending from near Little Arbor Vitae Lake on the east to Broken Bow Lake on the west, skirting the southern border of Vilas County, and at the same time the region of extremely abundant lakes and bogs, passing

* This is contribution 134 from the botanical laboratories of Butler University, Indianapolis, and reports 111 from the Limnological Laboratory of the Wisconsin Geological and Natural History Survey, University of Wisconsin.

from more universal pine barren habitat to one where northern hardwoods are more frequent intruders.

## Soil and Topographic Features

Little need be said in repetition of the soil and topography of the Vilas County neighborhood. Deposits of Late Wisconsin glaciation determine both features, but the region is somewhat farther south from the high Winegar end moraine than the two series of bogs referred to in the introduction. The soil is chiefly sand and gravel with intermittent limited areas of clay and loam. The county itself is known for its abundance of lakes and bogs and lack of agricultural activities. The narrow, and limited intrusions of better soil supported primarily northern hardwoods, and the sandy areas were controlled by Pinus.

While the southern border of Vilas County marks the beginning of decrease in number of lakes per unit area, the topography is still rolling, but strips of better soil are perhaps more frequent, and bogs are not so numerous as in the major part of the county. The ridges also are obviously less high than in and near the Winegar moraine.

## Description of The Bogs

### *Mud Creek Bog*

Mud Creek Bog is of the valley type. The boring was made in the approximate linear center, about a quarter mile north of highway 7. (R. 7 E., T. 39 N., Sec. 26, n.e. quarter). Sandy ridges border the bog and straggling pine forests still control the tree stratum of the adjoining forest. The rim of the depression supports a sparse stand of *Larix laricina* and *Picea mariana.* The surface cover for the most part consists of Sphagnum, while the center is still in a sedge meadow stage of succession.

### *Mid Lake Bog*

The deep-set small bog is north of Mid Lake, only a low sandy wall separates it from the lake. It is 4 miles s.e. of Woodruff in Oneida County, along highway 47. The Sphagnum mat is very quaky, but Chamaedaphne has invaded in scattered clumps.

A number of small dead *Picea mariana* indicate a former invasion of the mat by trees. The boring was made approximately in the center of the depression. The bordering uplands had apparently been covered chiefly by Pinus, but some hardwoods still remains a short distance from the bog near Mid Lake.

### *Bog E*

For lack of a good location name for this little bog we resort to the alphabetical system used in the Trout Lake series by Potzger-Richards (1942). Bog E is located on highway 70, three miles west of the intersection of 51 and 70. The bog is small, perhaps 200 by 300 feet, and represents the kettle-hole type. The mat is completely covered by sedges, Chamaedaphne, and Andromeda, while Sphagnum and Polytrichum form a dense mat cover. Sandy ridges, varying from five to twenty feet in elevation, form the skirting border. *Picea mariana,* Larix, and a few *Pinus strobus* specimens have invaded the mat in scattered clumps. The trees on the adjoining ridges are primarily aspen, a few *Pinus strobus* and some *Prunus pennsylvanica.* The boring was made in the center of the depression.

### *Broken Bow Lake Bog*

This bog is located in R. 4 E., T. 39 N., Sec. 26 (s.w. quarter). Steep slopes of sandy and gravelly hills rise abruptly from the rim of the kettle-hole. The northeast section of the depression is still an open lake and only a narrow, shallow, sandy and gravelly bar separates the two parts of a once larger lake. The mat is in the sedge meadow stage of succession, studded with abundant clumps of Chamaedaphne, which served as safer support on the mat, which sagged a foot or more under the weight of a human being. Boring was made in the approximate center of the depression. The vegetation along the shore is primarily aspen with scattered colonies of *Pinus strobus* and *P. resinosa,* but stands of northern hardwoods were frequent westward from the bog.

## METHODS

Samples collected in the field were taken with the movable sleeve, cylinder-type borer. A small amount of peat was taken

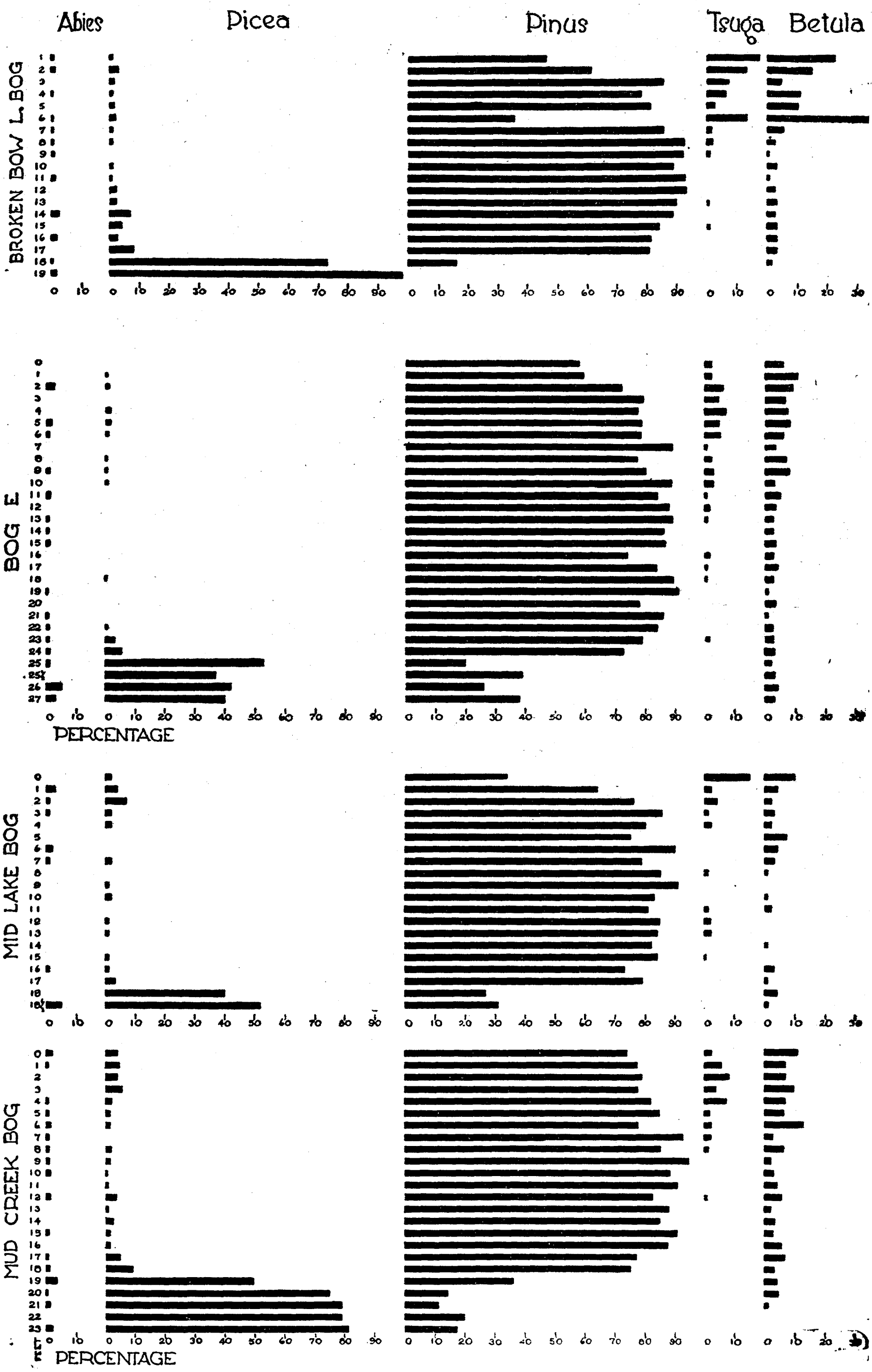
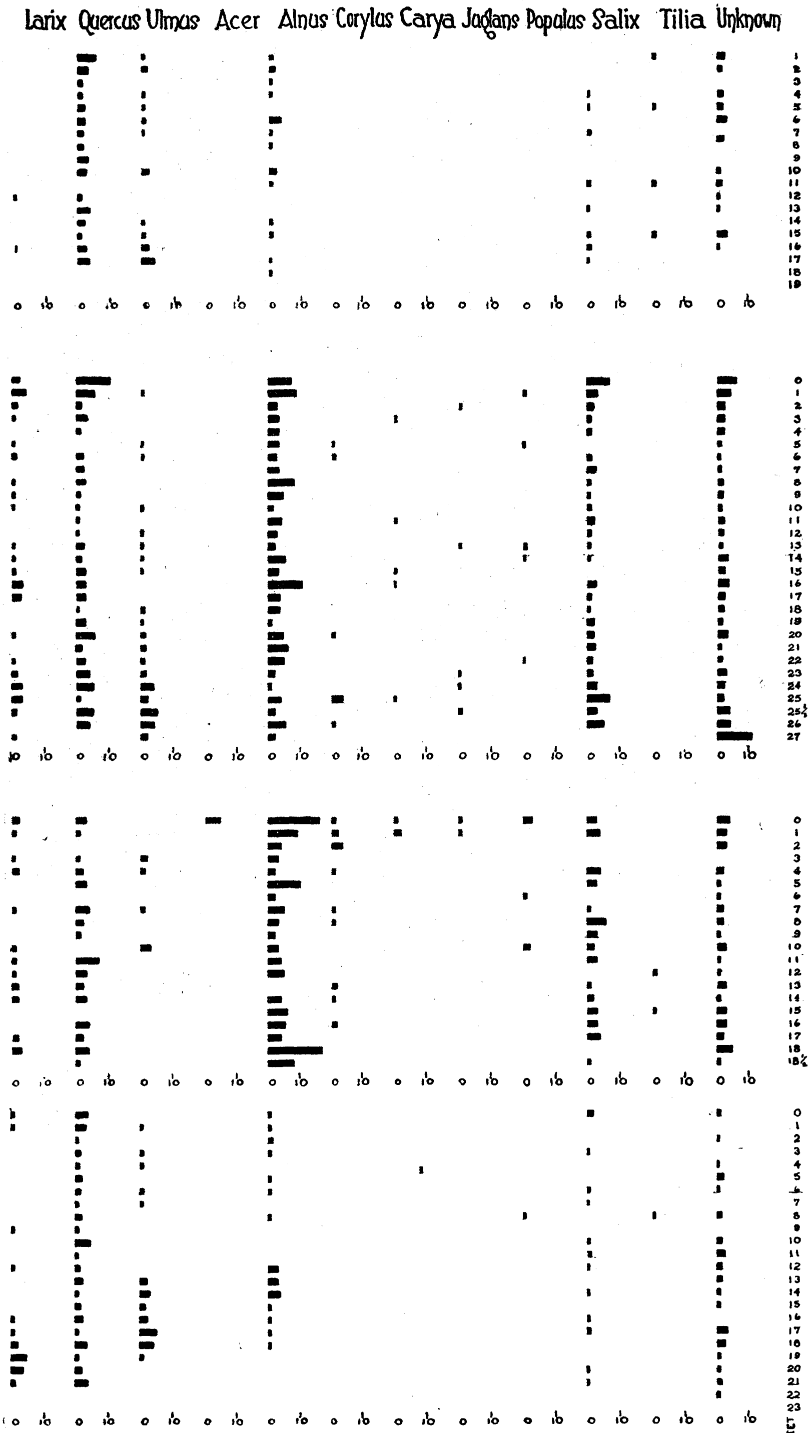



FIGURE 1. Pollen profiles of four bogs along the southern border of Vilas County, Wisconsin


Larix Quercus Ulmus Acer Alnus Corylus Carya Juglans Populus Salix Tilia Unknown
FEET

from the center of the core, placed into a bottle properly labelled as to bog and foot-level designation. No preservatives were added. In the laboratory the bottles were sealed by dipping the stoppers into paraffin to prevent drying out of the sample. Slides were prepared according to the Geisler (1935) method, and staining was with 5 percent aqueous solution of gentian violet. 200 pollen grains were counted for each foot-level. Pinus is, again, listed as genus only because we could not satisfactorily separate pollen of the various species.

## RESULTS

All four bogs show a similar vegetational succession up to the last three or four topmost levels. Picea is important in all while early sediments were being deposited, however, only Broken Bow Lake Bog recorded absence of Pinus in the lowest level. Records from some bogs indicate a Picea-Pinus association (Fig. 1). Persistence of Picea through numbers of foot-levels varies, being longest in the Mud Creek and Broken Bow Lake bogs (Fig. 1). All four bogs, however, show an extremely long and uninterrupted Pinus dominance following displacement of Picea, involving 75 to 80 percent of total number of levels. In the Mud Creek Bog Pinus dominance persisted to the very topmost level. The more western Broken Bow Lake Bog, with increasing Betula and Tsuga (up to 40 percent of the pollen counted) in the upper levels, indicates invasion by northern hardwoods, which still controls on better soils in locations near to and westward of the bog. The same trend is indicated in the surface level of Mid Lake Bog, while a mixture of broad-leaved genera in the upper fourth of the levels in all bogs represents, perhaps, the same climatic change, which in areas of better soils, exemplified by Broken Bow Lake Bog, initiated the local dominance by northern hardwoods, and as pointed out by Potzger (1942), and Potzger-Richards (1942) marks the beginning of the two prominent forest cover types in the lake region. It may be well to point out again that Tsuga is definitely a later migrant into the region than Pinus and indicates association with broad-leaved species.

According to all appearances, Betula, Tsuga, and *Acer saccharum* are capable of enduring a more rigorous climate than

Quercus. This latter genus is characterized by a long, non-aggressive presence in all pollen profiles, frequently showing a tendency towards greater prominence in the forest canopy while the topmost sediments were laid down, as in the Broken Bow Lake Bog and Bog E (Fig. 1), never, however, being of apparent sufficient significance to warrant reading into its representation a major climatic change.

Broken Bow Lake Bog shows a most unusual break in high Pinus dominance at the six-foot level, where percentage dropped from 85½ to 35¼, only to rise again in the five-foot level to 81 percent. There is no comparable fluctuation in Bog E, only 10.5 miles east, so one must consider it a local variation, indicating perhaps a conflagration which destroyed the pine forests adjacent to the lake, an early succession of *Betula papyrifera,* or a better transportation facility through open territory from dominants of the nearby northern hardwoods.

## DISCUSSION

The succession along a 25-mile stretch immediately south of the region with abundant lakes (Vilas County) was for 75 to 80 percent of the foot-levels of all bogs the same as in Vilas County about Trout Lake, as recently reported by Potzger-Richards (1942). The profile from Mud Creek Bog correlates exactly with those from the Trout Lake neighborhood. The variation in prominence of Pinus and broad-leaved species associated with Tsuga reflects a heterogeneous habitat which makes a microclimatic selection in a generally uniform macroclimate, comparable somewhat to the Trout Lake region where according to Potzger-Richards (1942) Pinus retained dominance to the topmost level, and the Gillen Nature Reserve, twenty miles north of the lake, where according to Potzger (1942) Betula and Tsuga assumed a dominant role in the upper third of the sediments in four bogs of that region. Since northern hardwoods, Betula, Acer, Tsuga, dominate the forests about these bogs today it seemed a justified conclusion that the decline of Pinus in that region marked a moderating climatic change which favored northern hardwoods, and made Pinus assume a post-climax status, maintained by edaphic factors of sandy soil. The bogs of the present study reflect the same general tendencies as the two sets of bogs referred to above, i.e. two major climatic changes, one terminating dominance of Picea or Picea-Pinus, initiating a very long Pinus dominance, and a more recent moderation of temperature with a likely increase in moisture, which favored the broad-leaved forest association with Tsuga, while Pinus maintains a status of post climax in less favorable soil habitats, as at the Mud Creek Bog region. Wilson-Galloway (1937) recognize the same climatic change when they say, "The microfossils indicate that the regional flora was dominated early in its history by a coniferous element, and that this was gradually replaced by Angiosperms." It seems strange that these authors record no Quercus, which we found so persistent in small percentages in all bogs studied in the Vilas County neighborhood. We also are of the opinion that it distorts the picture of a pollen profile to include pollen of herbaceous plants and spores of mosses or Pteridophytes, and weigh them the same as pollen of trees in the pollen profile, as Wilson-Galloway (1937) and Artist (1939) have done.

The same major climatic changes and waves of forest succession discussed above moved north, east and westward from the southern edge of Late Wisconsin glaciation in Indiana, except that the Pinus dominance became more protracted with advance into northern latitudes, as shown by Potzger-Wilson (1941) for northern Indiana and southern Michigan. Along the prairie-forest ecotone of southern Minnesota, as shown by Artist (1939), as well as along the Atlantic coast in the glaciated part of northern New Jersey, as reported in a recent manuscript by Potzger-Otto (1942), almost complete dominance by Pinus was followed by a long-persisting Pinus-Quercus association. A similar succession, ending in a long Pinus-Quercus dominance is also reported by Hansen (1939) for the Driftless Area of Wisconsin.

## Summary and Conclusion

1. Included in this study are pollen profiles from four bogs along the southern border of Vilas County, Wisconsin, representing a linear east-west distance of approximately 25 miles.

2. Forest succession is very similar in all four bog areas except for the time represented by the upper foot-levels.

3. Succession is from Picea or Picea-Pinus to a very long and complete Pinus dominance, to Betula-Tsuga, or to a group of broad-leaved genera. In the Mud Creek Bog profile Pinus showed dominance to the topmost level.

4. Differences in importance of coniferous and broad-leaved genera in the uppermost foot-levels are attributed to differences in edaphic factors, and really indicate the most recent moderation in climate, which in some regions favored the invasion by northern hardwoods, maintaining Pinus as post climax in sandy regions.

## Acknowledgments

The senior author expresses his appreciation to the Wisconsin Geological and Natural History Survey for the opportunity to serve on the staff during the summer of 1940; and to the Wisconsin Alumni Research Foundation for the grant of funds which supported the field work of this investigation. We thank the Messrs. Thomas H. Flanigon and Charles Lines, members of the staff at the Limnological Station, for assistance rendered in the boring work. To Miss Jane L. Goodlet, botany major at Butler University, we are indebted for the lettering on the chart.

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# PHYSICAL AND CHEMICAL EVIDENCE RELATING TO THE LAKE BASIN SEAL IN CERTAIN AREAS OF THE TROUT LAKE REGION OF WISCONSIN

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## INTRODUCTION

A general physical, chemical and biological survey of some 550 lakes and lakelets situated in the northeastern lake district of Wisconsin was made between 1925 and 1932. On the basis of certain characteristics noted in this survey, these bodies of water have been separated into three different classes. (1) Somewhat more than one-third of them have neither inlets nor outlets and they have been designated as seepage lakes. (2) A second group has no definite inlets, but they have temporary outlets whenever their water levels reach unusually high stages during periods of above normal precipitation; they have been called intermittent drainage lakes. (3) The third group consists of lakes with permanent outlets and they have been called drainage lakes; this group includes somewhat more than half of the 550 lakes included in the survey.

All of the lakes in this northeastern district occupy basins in glacial deposits which range from 40 to 70 meters (130 to 234 ft.) in depth. The large number of landlocked lakes in this district indicates that the drainage system is still in a youthful stage of development. This region was subject to several ice invasions during the Glacial Period and the last ice sheet brought in glacial material that contained only a comparatively small amount of carbonates and leaching since the retreat of the ice has helped to reduce the stock of carbonates in the upper stratum of the deposits. The scarcity of carbonates in the sandy soil is well shown by its acidity; for agricultural purposes in many cases, it would require as much as five metric tons of lime per hectare of land to correct this acidity. The lower strata of the glacial deposits, however, have a larger supply of carbonates; this is shown by the carbonate content of well borings and also by that of the deeper strata of the ground water. This scarcity of carbonates in the upper part of the deposits has an important bearing upon the chemical content of the waters of most of the seepage lakes which will be discussed later. The

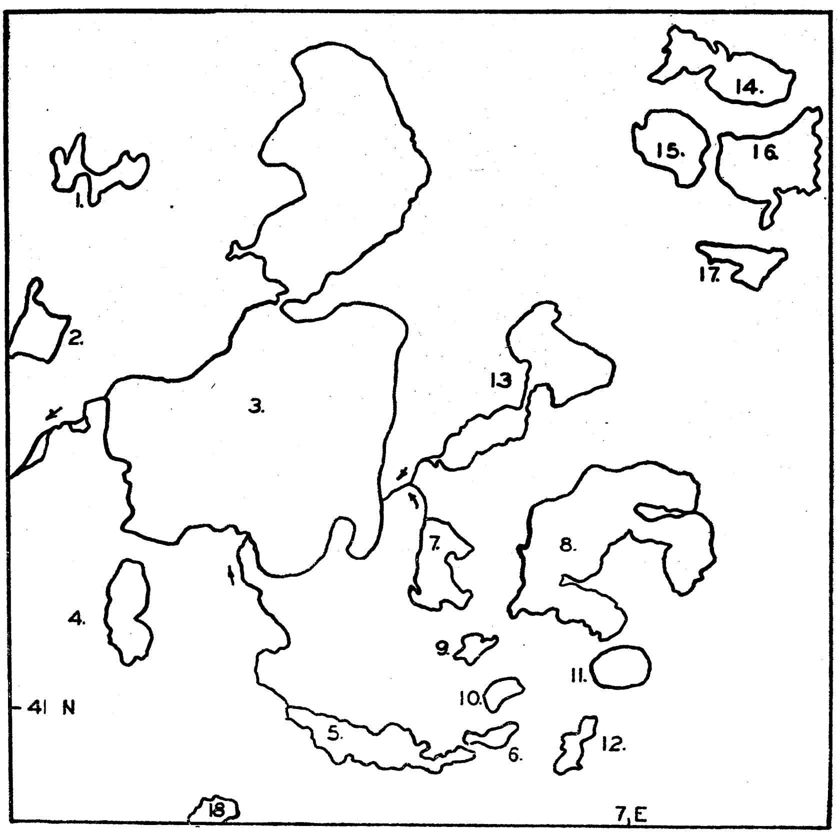


FIGURE 1. Sketch map of Trout and neighboring lakes. The names of the various lakes are as follows: 1 Day; 2 Diamond; 3 Trout; 4 Silver; 5 Mann; 6 Emerald; 7 Little John; 8 Muskellunge; 9 Little John, Jr.; 10 Weber; 11 Crystal; 12 Fallison; 13 Allequash; 14 Lost Canoe; 15 Pallette; 16 Escanaba; 17 Nebish; 18 Vandercook.

various bodies of water that have been studied range in size from lakelets less than a hectare (2.5 a.) in area to Lake Vieux Desert with an area of 1934 ha. (4780 a.). Their depths vary from a meter or two in the shallowest to a maximum of 35 m. (115 ft.) in Trout Lake.

The large number of seepage lakes in this district together with the character of the glacial deposits in which they are situated naturally raised questions regarding the basin seals which maintain the waters in these basins, particularly the seals above the level of the ground water table. The special studies on which this report is based were made on a small group of lakes lying south and southeast of Trout Lake on which the Liminological Laboratory is located (Fig. 1); some observations were also made on two lakes situated on the west side of Trout Lake (Diamond and Silver) and on a small group of lakes at the south end of the Kawaguesaga-Tomahawk chain in the vicinity of the American Legion Camp (Fig. 3). These latter lakes together with some of those situated in the Trout Lake region are listed in Table 1.

Particular attention was given to the seepage lakes because their waters are usually very soft and thus offer a good means of determining the relation of the lake waters to the surround-

TABLE 1. Elevations above sea level of some lakes in the Trout Lake region of northeastern Wisconsin. The survey was made during the summer of 1930. The different types of lakes are indicated by the following letters: S = seepage; ID = intermittent drainage; D = drainage lake.

| Lake | Type | Elevation | |
|---|---|---|---|
| | | Meters | Feet |
| Crystal | S | 502.3 | 1648.0 |
| Diamond | S | 493.6 | 1619.5 |
| Emerald (Ruth) | S | 500.5 | 1642.3 |
| Fallison (Long) | S | 499.2 | 1637.8 |
| Little John | D | 498.0 | 1633.9 |
| Little John Jr. | S | 499.6 | 1639.0 |
| Mann | D | 497.5 | 1632.3 |
| Muskellunge | ID | 500.7 | 1642.9 |
| Silver (Sparkling) | ID | 494.8 | 1623.5 |
| Trout | D | 492.1 | 1614.6 |
| Weber | S | 501.1 | 1644.0 |
| Kawaguesaga-Tomahawk chain | D | 483.4 | 1586.0 |
| Big Carr | S | 485.4 | 1592.7 |
| Bird | S | 485.0 | 1591.3 |
| McGrath | S | 485.8 | 1594.0 |

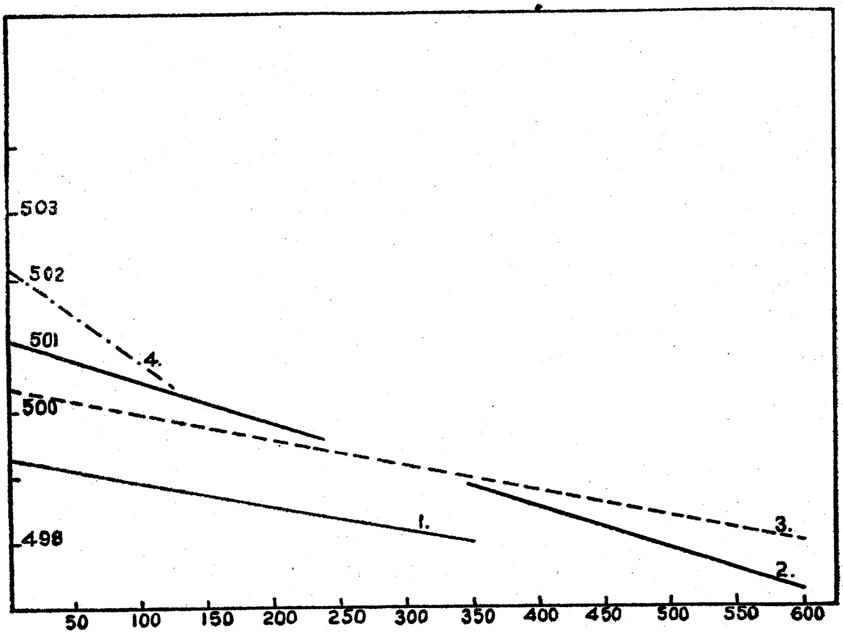


FIGURE 2. The curves in this diagram show the differences in elevation between neighboring lakes. The ordinates show the surface elevations of the lakes and the abscissae the distances between the lakes; both are given in meters. Curve No. 1 shows the relation of Little John Jr. to Little John; No. 2 that of Weber and Mann lakes; No. 3 that of Muskellunge and Little John; No. 4 that of Crystal and Muskellunge.

ing ground waters. The watersheds of these lakes are comparatively small so that correspondingly small amounts of water are derived from this source; even the water which is contributed by these limited watersheds contains only a small mineral content because the soil is poor in carbonates and other readily soluble inorganic constituents. This leaves only the rain and snow precipitated on their surface as the chief source of their water supply and this meteoric water holds only small amounts of inorganic materials in solution. Thus the Ca content of the waters of the typical seepage lakes rarely exceeds 5 mg/l, in the great majority it is less than 3 mg/l. These seepage lakes lose water only by evaporation and by seepage through the ground and the softness of their waters suggested that this characteristic might serve as a good indicator for the determination of the rate of loss by seepage and thereby show the relative effectiveness of the basin seal in preventing excessive loss of water by this process.

## METHODS

Both physical and chemical methods were employed in these studies. The former was based on an accurate determination of the surface levels of the various lakes, including both seepage and drainage types, in the areas that were investigated. For this purpose a line of levels was run from Trout Lake to the several lakes in that area; the elevation of Trout Lake had previously been carefully determined by members of the staff of the Armour Institute of Technology which has a summer surveying camp on the north part of Trout Lake and where a bench mark was established. At the time the elevations were run in 1930, the surface of Trout Lake had an elevation of 492.1 m. (1614.6 ft.) above sea level. The elevation of the Kawaguesaga-Tomahawk chain was established at the time they were surveyed for water storage purposes and it was used as a basis for the survey of the three seepage lakes situated near Little Tomahawk Lake. Fries (1938) and Broughton (1941) ran lines of levels to some of the lakes they studied and the results are included in their reports. In the chemical studies, the mineral content of the lake waters was compared with that of the adjacent ground waters, especially with reference to the Ca and Mg content.

## ACKNOWLEDGMENTS

Cordial thanks are due several members of the staff of the Armour Institute surveying camp for their interest and assistance in making the level surveys and also several students of the surveying camp who assisted in the work.

## SURVEYING RESULTS

The elevation surveys made in July and August, 1930, are given in Table 1. The lakes listed in this table from Crystal to Silver, inclusive, lie in the drainage basin of the Trout River, which is the outlet of Trout Lake; in fact all of the water of the drainage lakes listed in this part of the table flows through

Trout Lake (Fig. 1). The surface levels of all lakes in this group are well above that of Trout Lake; as might be expected, the elevations of the seepage lakes in the group are greater than those of the drainage lakes. Crystal has the highest elevation and Weber ranks second. Some interesting comparisons of lake levels can be made from the results given in Table 1. Crystal Lake, for example, is only 100 m. (328 ft.) from Muskellunge at the nearest point, but the basin seal of the former is such as to hold the surface 1.6 m. (5.2 ft.) above that of the latter, as indicated in Figure 2, curve No. 4. The table shows that the level of Muskellunge, in turn, is 2.7 m. (9.0 ft.) above that of Little John Lake which is 600 m. (1968 ft.) distant as shown in Figure 2, No. 3. Little John Jr. is only 350 m. from Little John and its surface is 1.6 m. (5.2 ft.) above that of the latter (Fig. 2, No. 1). Weber Lake is 600 m. from Mann, the nearest drainage lake, and its surface is 3.6 m. (11.7 ft.) above that of the latter. Mann Lake is fed by springs and seepage water from Weber Lake undoubtedly makes a contribution to them (Fig. 2, No. 2). Another marked difference in level within a comparatively short distance is that between the surfaces of Silver and Trout lakes (Fig. 1); the former is only 175 m. (574 ft.) from the southwest corner of Trout Lake, but the surface of the former was 2.7 m. (8.9 ft.) above that of the latter at the time of the survey in 1930.

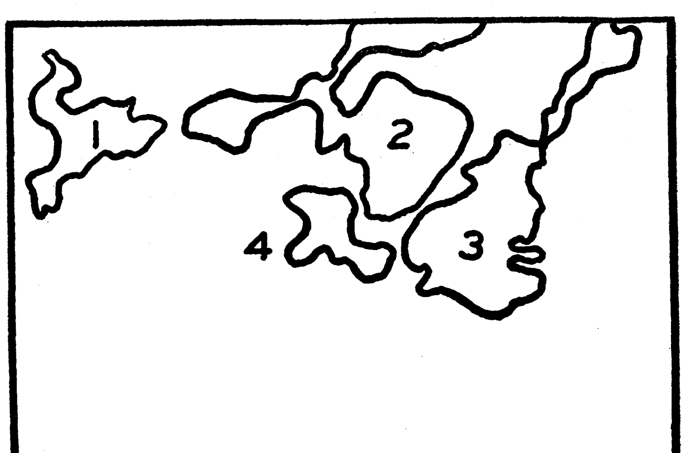


FIGURE 3. Sketch map of Little Tomahawk and neighboring seepage lakes. The names are as follows: 1 Bird; 2 Little Tomahawk; 3 Big Carr; 4 McGrath.

The group of lakes given in the last four items of Table 1 lies in the drainage basin of the Tomahawk River. The three seepage lakes in the group are nearest Little Tomahawk Lake (Fig. 3) which belongs to the Kawaguesaga-Tomahawk chain of drainage lakes, all maintained at approximtely the same level as a water storage reservoir. A striking difference in level as compared with the intervening distance is found between Big Carr and Little Tomahawk (Fig. 4, No. 1); the sand and gravel

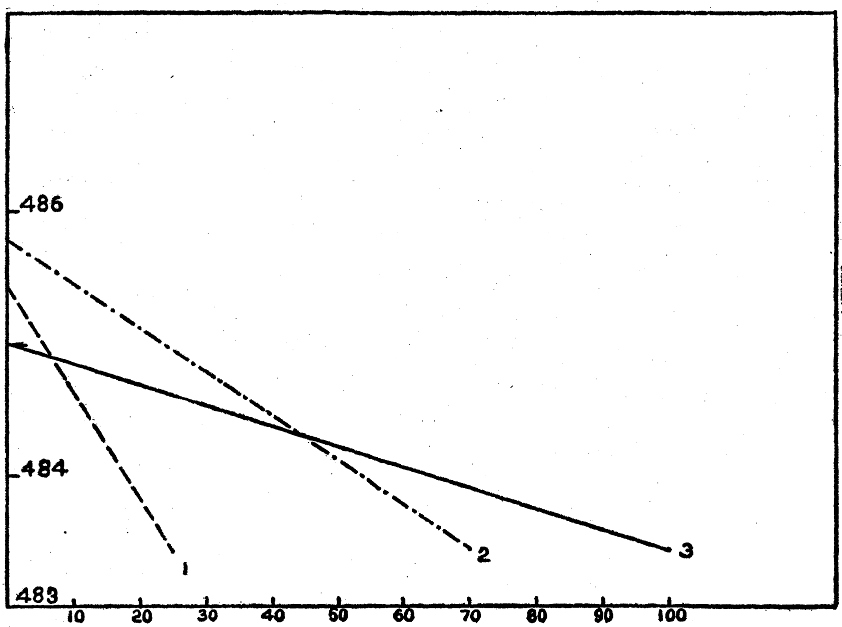


FIGURE 4. The curves in this diagram show the differences in elevation between neighboring lakes. The ordinates show the surface elevations of the lakes and the abscissae the distance between the lakes; both are given in meters. Curve No. 1 shows the relative elevations of Big Carr and Little Tomahawk; No. 2 those of McGrath and Little Tomahawk; No. 3 those of Bird and Little Tomahawk.

ridge separating them is a little less than 25 m. (80 ft.) wide, but the surface of Big Carr was 2.0 m. (6.7 ft.) higher than that of Little Tomahawk in the summer of 1930. The ridge between McGrath and Little Tomahawk is 70 m. (230 ft.) wide at its narrowest point, but the surface of the former was 2.4 m.

(8.0 ft.) above that of the latter at the time of the survey (Fig. 4, No. 2). Bird Lake is 100 m. (328 ft.) from Little Tomahawk and its surface was found to be 1.6 m. (5.2 ft.) above that of the latter (Fig. 4, No. 3).

Fries (1938) made a study of the relation of the levels of a number of lakes to each other and also to the levels of the ground waters surrounding them. His studies were made in the summer of 1936 and they dealt with the lakes in the area lying just south of the Muskellunge and Little John lakes, more especially with those in the vicinity of Weber Lake (Fig. 1). He dug pits down to the level of the ground water in various places around several of the lakes and then ran levels from the surfaces of the lakes out to the surfaces of the ground waters in these pits. The results showed that the ground water table sloped gradually from lakes with higher to neighboring lakes with lower elevations; this situation was considered as evidence that there was a more or less definite movement of the water from the former toward the latter. In some cases the ground

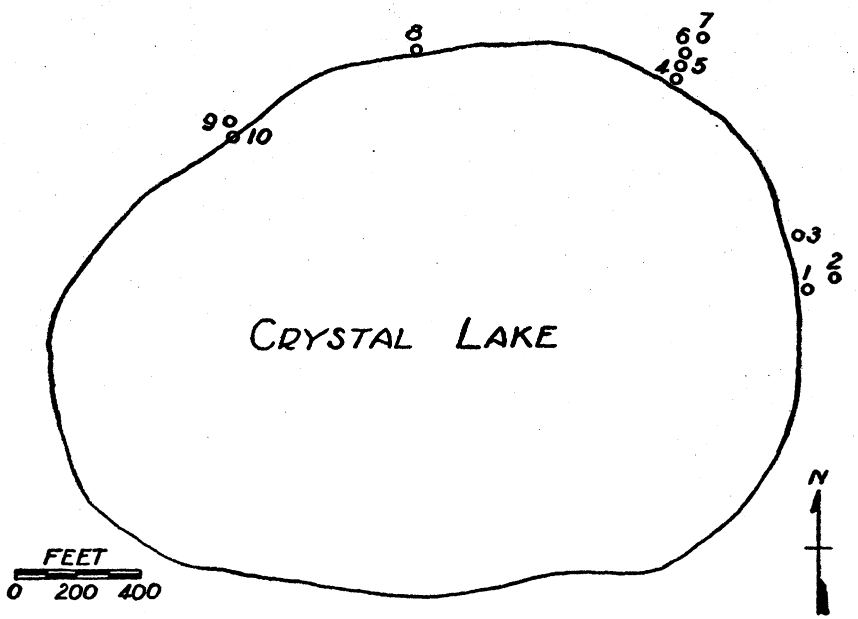


FIGURE 5. Sketch map of Crystal Lake showing the location of the pits on its shores from which samples of ground water were taken for the chemical analyses.

water table was somewhat higher than the lake surface on one side and lower on all other sides, but in most instances the ground water sloped away from the seepage lakes in all directions. In early July the surface of the ground water in one of the pits on the east side of Weber Lake was 12.5 cm. (5 in.) higher than that of the lake, but in all of the other pits around the lake the ground water level was below the surface of the lake; near the end of August, however, the ground water table in all pits around Weber Lake ranged from 7.5 cm. to 45 cm. below the surface level of the lake. The ground water table not only in the Weber Lake pits but also in those on the shores of other lakes was lower at the end of August than it was in early July; the amount of the decline during this time varied from a minimum of 10 cm. (4 in.) to a maximum of 23 cm. (9 in.). In 1937 Broughton (1941) determined the elevations of 9 seepage lakes situated south of the Muskellunge Moraine in connection with other observations on them, but he did not ascertain their relations to the ground water table in that region.

Some observations on the changes in the surface level of Weber Lake may be mentioned in this connection. On July 6, 1940, a calibrated stake was placed in this lake and readings were taken at regular intervals during the summer. Light rains during the first week brought the lake surface up to 1.75 cm. above the zero point and heavier rains during the week of July 15-22 brought the level up to 7 cm. above zero. Following this date there was a gradual decline in the level of the water until it reached 1.5 cm. below the zero mark on August 19. The following week brought the level up half a centimenter so that the last reading taken on August 26 showed 1 cm. below the zero point. During these two months, therefore, the net decline of the lake level was only one centimeter, but the total change during the period was 8.5 cm.

## Chemical Results

Some observations on the mineral content of the ground water relative to that of the lake water were made on Crystal Lake in August 1934 and again during the summer of 1935; such studies were also extended to some other lakes in 1935-37. As already indicated pits were dug down to the ground water

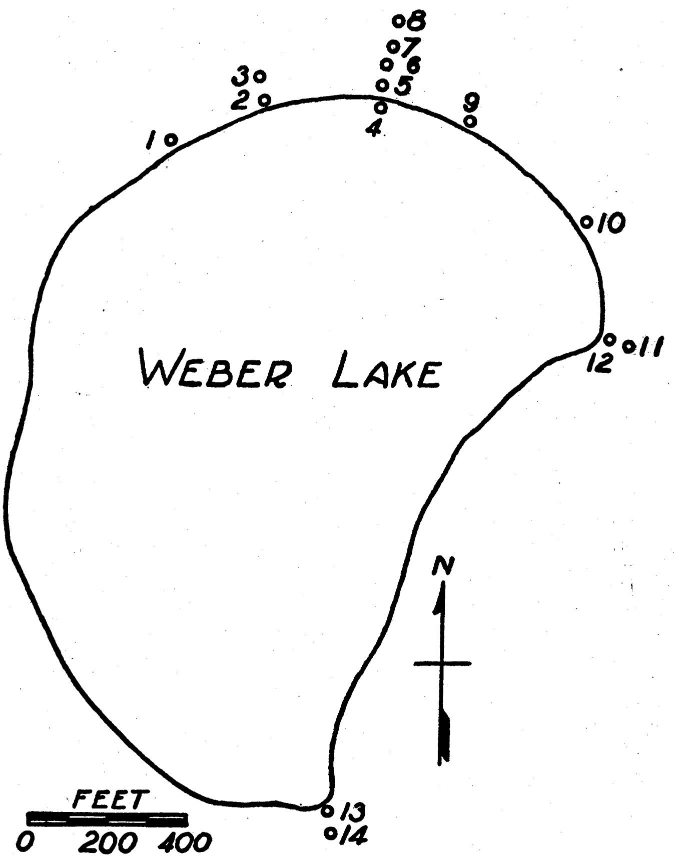


FIGURE 6. Sketch map of Weber Lake showing the location of the pits on its shores from which samples of ground water were taken for the chemical analyses.

level on the shores of the various lakes at distances of a quarter of a meter up to 8 m. or more from the edge of the lake water and samples of the water that seeped into these pits were collected for chemical analyses, which consisted principally of determinations of Ca and Mg. In some of the experiments, a regular well point with the upper half of the screens soldered shut was driven down to different depths in the pits and samples of the water that seeped into it were analyzed. The well point could be driven down 25 to 50 cm. below the ground water table for the purpose of getting samples of the deeper ground water. In one experiment the well point was driven into the bottom of the lake where the water was about 15 cm. deep and a sample of the ground water under the lake itself was thus obtained for analysis.

These chemical investigations were confined chiefly to Crystal and Weber lakes in 1934-35; the various stations are indicated on the maps shown in Figures 5 and 6. The results of some of the analyses are given in Table 2. It will be noted that the samples taken on the north side of Crystal Lake (Fig. 5) contained six to eight times as much Ca as the surface water of the lake. As previously mentioned, Fries found that the ground water table sloped from Crystal down to Muskellunge, the neighboring lake on the north, whose surface was 1.6 m. lower; thus any seepage water entering the ground along the north side of Crystal would carry the more mineralized ground water toward Muskellunge Lake and tend to prevent the increase in the Ca content of the water of the former along this side of the lake. In this connection it may be noted that the mean Ca content of five samples of surface water taken in Muskellunge Lake in three different years was 6.25 mg/l as compared with 0.84 mg/l in Crystal. Further, the amount of Ca found in the surface water of Muskellunge was about the same as that of the ground water along the north shore of Crystal Lake; it was also about the same as that found in the waters of five wells located on the shores of Muskellunge which ranged from 5.7 to 7.0 mg/l. A sixth well had 3.2 mg/l and a seventh 11.7 mg/l. The water of a pit located 8 m. from the water's edge at the northeast corner of Crystal Lake yielded 11.8 mg/l and that of one behind the old ice rampart (about 25 m. from the lake) contained 13.72 mg/l (Stations 6 and 7, Fig. 5).

The beach at the east end of Crystal Lake presents a very different picture from that of the north side. It is a wide gently sloping beach consisting of loose sand that is light gray in color and this sand extends well below the ground water table. The sides of the pits dug here caved in very rapidly when the ground water was reached and thus prevented a determination of the exact depth of this loose sand. The results given in Table 2 show that the ground water in the pits at the east end of the lake contained less than half as much Ca as that of the pits of the north side; in fact one sample taken from a pit at the east end yielded only a little more Ca than the surface water of the lake. Two kegs with holes bored in them to facilitate the entrance of the ground water were placed in pits 1 and 2 (Fig. 5) at the east end of the lake and samples were taken from them over a period of several days; one was located 1 m. and the other 3 m. from

TABLE 2. Calcium content of the lake waters and of the ground waters taken from pits on the shores of Crystal and Weber lakes. (See maps, Figs. 5 and 6, for location of pits.)

| Lake | Stations | Date | Distance from edge of water | Ca mg/1 |
|---|---|---|---|---|
| Crystal | 1 | 8/26/35 | 1 m. | 3.26 |
| | | 8/28/35 | " | 1.98 |
| | | 8/29/35 | " | 1.04 |
| | 2 | 8/26/35 | 3 m. | 3.30 |
| | | 8/28/35 | " | 2.11 |
| | | 8/29/35 | " | 1.36 |
| | 3 | 8/16/35 | 2 m. | 1.22 |
| | 4 | 8/10/34 | 0.5 m. | 6.24 |
| | 5 | 8/10/34 | 3 m. | 4.76 |
| | 6 | 8/10/34 | 8 m. | 6.60 |
| | 7 | 8/10/34 | 25 m. | 13.72 |
| | 8 | 8/ 9/34 | 3 m. | 6.16 |
| | 9 | 8/ 9/34 | 8 m. | 11.80 |
| | 10 | 8/ 9/34 | 3 m. | 5.20 |
| | Surface | 8/16/35 | | 0.84 |
| Weber | 1 | 8/ 9/35 | 1 m. | 2.64 |
| | 2 | 7/31/35 | 2 m. | 2.74 |
| | 3 | 7/31/35 | 4 m. | 2.60 |
| | | 8/ 1/35 | " | 2.68 |
| | 4 | 8/14/35 | 2 m. | 2.08 |
| | 5 | 7/31/35 | 1 m. | 7.60 |
| | | 8/ 1/35 | " | 8.40 |
| | | 8/ 2/35 | " | 7.32 |
| | 6 | 7/31/35 | 3 m. | 18.55 |
| | | 8/ 1/35 | " | 19.00 |
| | | 8/ 2/35 | " | 17.84 |
| | 7 | 8/ 7/35 | 4 m. | 1.32 |
| | 8 | 8/14/35 | 8 m. | 0.68 |
| | 9 | 8/14/35 | 1 m. | 1.56 |
| | 10 | Boat landing | | |
| | 11 | 7/31/35 | 3 m. | 1.94 |
| | | 8/ 1/35 | " | 2.64 |
| | | 8/ 7/35 | " | 1.96 |
| | 12 | 7/31/35 | 1.5 m. | 4.16 |
| | | 8/ 1/35 | " | 4.20 |
| | 12a | 7/31/35 | 1 m. | 1.44 |
| | | 8/ 6/35 | " | 1.60 |
| | | 8/ 7/35 | " | 1.04 |
| | 13 | 8/ 6/35 | 1 m. | 1.36 |
| | | 8/ 7/35 | " | 1.60 |
| | 14 | 8/ 7/35 | 3 m. | 1.28 |
| | Surface | 8/ 6/35 | | 1.35 |

the edge of the lake water. At the time of installing the kegs, the Ca content of the water which seeped into them was 3.26 and 3.30 mg/l respectively, but two days later the amount had fallen to 1.87 and 2.11 mg/l and on the third day the amounts were 1.02 and 1.12 mg/l. Apparently the digging of the pits brought in water from some source where the Ca concentration was somewhat larger than that of the surface stratum of the ground water, while the later samples consisted of water from the top stratum of the ground water. The extra water in the kegs was removed each time after the samples were taken in order to let another sample seep into the kegs for the next visit. A part of the decrease might also have been due to rain, but the field notes do not show any record of rain during the time of the experiment. The Ca content of the waters of two wells located at the east end of Crystal Lake may be given in this connection; that of the old well 10 m. (33 ft.) deep yielded 1.12 mg/l of Ca while that of a new well drilled in 1936 with a depth of 31 m. (102 ft.) contained 10.6 mg/l.

## Weber Lake

As indicated on the map (Fig. 6), the pits for the ground water studies around Weber Lake were located mainly at the north end of the lake with a few at the sound end. In a comparatively narrow region about the middle of the north shore, the quantity of Ca in the ground water was three to eight times as large as that in the pits on either side and in those at the south end of the lake. Two kegs were installed in pits at the north end of the lake in the high Ca region and samples of water were taken from them from time to time over a period of about a month. One of them was located 1 m. from the edge of the water in the lake and the other 3 m. (Stations 5 and 6, Fig. 6). In several instances two samples were taken from each keg at the time of a visit; one consisted of the water standing in the kegs and the other was taken after the kegs had been emptied and fresh ground water had seeped into them. In general the second sample yielded somewhat larger amounts of Ca than the first. Similar results were also obtained by using a well point; the ground water samples obtained by driving the point down 30 cm. from the bottom of a pit had somewhat smaller amounts of

Ca than those obtained by driving the point down 60 cm. Well point samples taken in pits at Stations 7 and 8 (Fig. 6), located 7 m. or more from the water's edge, yielded only 0.6 to 1.04 mg/l of Ca, thus showing that the high Ca region covered a relatively small area. The Ca content of the ground water at the south end of the lake (Stations 13 and 14, Fig. 6) was smaller than that found in most of the pits at the northern end. Regarding the Ca content of the surface water of Weber Lake, it may be said that lime was added during the summers of 1933 and 1934 in some fertilizing experiments. The concentration of the Ca was increased from 0.68 mg/l in 1932 to 1.86 mg/l on August 27, 1934. The concentration has decreased only a comparatively small amount since the latter year; on August 11, 1941, for example, it was 1.27 mg/l.

In 1936 Fries found a moderately high concentration of Ca in a pit located in the same general region on the north shore of Weber Lake. He also found that the ground water table sloped gradually from the south end of Weber toward Emerald (Ruth) (Fig. 1) which lies about 250 m. (820 ft.) south of it; the Ca content of the ground water in the vicinity of Emerald Lake was found to be about twice as large as that in the ground water at the south end of Weber Lake.

## Lakes South of the Muskellunge Moraine

Broughton (1941) investigated a group of bog, seepage and drainage lakes lying south of the Muskellunge Moraine in the summer of 1937. The surface elevations of nine of them were determined and surface samples of the water of 17 were subjected to chemical analyses; also pits were dug on the shores of eight of them in order to obtain samples of the ground water for chemical analyses. The ground water samples of seven pits on the shores of Witches Lake yielded 1.13 to 1.9 mg/l of Ca as compared with 1.35 mg/l in the surface sample of the lake; one of the pit samples had the same amount of Ca as the lake water, while four had a somewhat smaller and two a larger amount, so that the Ca content of the lake water and of the surrounding ground water was almost the same. This was the best correlation between lake and surrounding ground water noted for any of the lakes studied.

In four pits on the shores of Scaffold Lake, Broughton found that the quantity of Ca ranged from 4.2 to 13.4 mg/l, or more than a threefold difference, as compared with 3.29 mg/l in the surface water of the lake. In four pits on Erickson Lake, the only drainage lake which he investigated, the Ca content of the ground water varied from 4.4 to 6.4 mg/l; the samples from the two pits on the north shore of the lake yielded 4.4 and 4.9 mg/l and the two on the south shore contained 6.0 and 6.4 mg/l, as compared with 6.02 mg/l for the surface water of the lake. There was a rather wide range in the samples of ground water from the six pits on the shores of Vandercook Lake (Fig. 1, No. 18); the amount of Ca in them varied from a minimum of 0.7 to maximum of 4.1 mg/l, or almost a sixfold difference in quantity, as compared with 2.47 mg/l in the surface water of the lake.

## Discussion

The determinations of the surface elevations of the various seepage and drainage lakes show that there are considerable differences in the heights of neighboring lakes in the areas that have been studied. In all cases the seepage had higher elevations than the neighboring drainage lakes as might well be expected. The surveys also showed that there was a gradual slope of the ground water table from those with higher to neighboring lakes with lower elevations; this was found to be true between seepage as well as between seepage and drainage lakes. This slope of the ground water level may be taken as an indication of a certain movement of the water from those with higher toward lakes with lower surface levels. On the other hand the striking differences in elevation between lakes that are only short distances apart show that the lake basin seals of the higher lakes are quite effective in preventing the rapid percolation of water from those of higher to those with lower levels.

The chemical results obtained on the lake and ground waters also tend to show that the movements of the water out of the various seepage lakes take place very slowly. This is definitely indicated by the marked differences in the Ca content of the seepage lake waters and that of the surrounding ground waters; likewise these differences may be taken as good evidence that there is no rapid seepage of the ground water into these lakes whenever the elevation of the former happens to be above that of the latter. There is a certain general correlation between the mineral content of the lake water and that of the surrounding ground water; this is shown by the fact that the ground waters surrounding the soft water seepage lakes have a smaller mineral content than those surrounding lakes with harder waters. On the other hand the marked local variations in the mineral content of the ground waters found in the pits located on the shores of the seepage lakes tend to show that the outward movement of the soft waters of these lakes is not great enough to have more than a limited influence on the surrounding ground waters. Broughton (1941) also called attention to the marked variations in the mineral content of the ground waters surrounding the lakes that he studied and concluded that it showed a lack of free mixing of the lake and ground waters.

These local variations in the mineral content are also found in the deeper strata of the ground water as shown by the well waters. In 31 wells located on the shores of Trout Lake, for example, the Ca content of their waters ranged from a minimum of 1.52 mg/l to a maximum of 62.0 mg/l, as compared with an average of 11.4 mg/l in the surface water of the lake. Twelve of the 31 wells yielded a smaller amount of Ca than the lake water, with a mean of 5.46 mg/l or approximately half that of the lake water, and 19 yielded a larger amount, with a mean of 22.48 mg/l or almost twice as much as the lake water. These variations in Ca content were not correlated with the depths of the various wells, although the softest waters generally came from the shallowest wells, or those not exceeding 10 m. (33 ft.) in depth; some of the high Ca yielding samples, however, came from shallow wells. One sample from a well only 5 m. (16 ft.) deep had 59.4 mg/l of Ca. Well cuttings in this region show that calcareous material is much more abundant in the deeper, older layers of these glacial deposits than in the upper, younger strata. The more calcareous deposits were found to be 10 m. (33 ft.) or more below the present surface in several wells; its topography is undoubtedly irregular so that it comes still closer the surface in certain areas, which would account for the much harder waters of some of the shallow wells.

The large amounts of organic matter in the bottoms of the bog lakes make excellent seals for them. Also the mud deposits in the deeper waters of other seepage lakes and in those of the drainage lakes make good seals because they contain large percentages of organic matter and the inorganic materials in them are made up in large part of silt and other small particles which readily form a compact impervious bottom. The seals around the sandy, gravelly margins of these lakes, however, are not so clearly evident in all cases. Some of the pits showed definite compact clay strata varying from 5 cm. (2 in.) to more than 100 cm. (3 ft.) in thickness along the margins of the lakes, but many of them did not show such a stratum, so that the mechanism of the seal in these instances is still unknown. These sand bottoms extend out to depths of 3 m. (10 ft.) to 5 m. (16 ft.) and the area from the shoreline down to these depths include a rather large percentage of the area of the lake in some instances. In Crystal Lake for example, the sandy bottom extends out to a depth of approximately 5 m. and thus covers about one-third of the entire area of the lake. In Weber Lake also, the sandy bottom covers about 30 per cent of the entire area. The sand is fairly compact and the interstices between the sand grains contain a certain amount of organic matter which would help to make this bottom relatively impervious. Pennak (1940) reported that sandy bottom half a meter from the water's edge where the water was 8 cm. deep contained 0.2 to 4.6 mg. of dry organic matter per 10 cc. of sand. It is known also that bacteria are present in these bottom sands in considerable numbers. These studies show that the problem of lake basin seals in the areas that have been studied is a complex one which merits a much more extended investigation.

## SUMMARY

1. Studies of the basin seal of several glacial lakes situated in the Trout Lake region of northeastern Wisconsin were made.

2. Determinations of the elevations of a number of these lakes showed that the bottom seals were sufficiently water-tight to hold the surfaces of some them a meter or two above those of neighboring lakes even when they were only short distances apart (25 to 150 m.).

3. The ground water table sloped from lakes with higher to neighboring lakes with lower elevations.

4. Chemical analyses demonstrated marked differences in the mineral content of the lake water and the surrounding ground water, thus showing that seepage of the former into the latter or vice versa took place very slowly due to the effectiveness of the lake basin seals.

## Literature

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# FLUCTUATIONS IN THE ANIMAL POPULATIONS OF THE LITTORAL ZONE IN LAKE MENDOTA[1, 2]

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The summer populations of the limnetic and profundal regions of Lake Mendota have been estimated by Birge and Juday (1922) and Juday (1922). Muttkowski (1918) surveyed the invertebrates of Lake Mendota. His work offers an excellent natural history report of the organisms found in the littoral region, notably insects. The fluctuations of animal populations inhabiting the plants of the littoral zone, however, have not been measured quantitatively.

Since nearly all of the game and pan fish of Lake Mendota frequent the plant zone throughout the summer, this region no doubt serves a very important role in the food and cover requirements of the fish.

Fassett (1940) in a survey of the literature on the role of aquatic plants in the fish-plant relationships found few quantitative observations which measured the benefits of plants to fish. It was the object of this study, therefore, to estimate some of the benefits of this habitat to fish; to measure also the populations of small fish inhabiting it. Moreover, the greater quantity[3] of plants in Lake Mendota as compared with northern Wisconsin lakes further emphasizes the need for learning more of their importance in the plant-fish-relationship as a contribution to comparative Wisconsin limnology.

In review of some of the workers who have sensed the importance of the value of plants to fish we cite:

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[1] This project was supported by a grant from the Wisconsin Alumni Research Fund.

[2] Appreciation is due Drs. N. C. Fassett and L. E. Noland for helpful suggestions during the course of this project.

[3] Rickett (1921) estimated Lake Mendota's crop of aquatic plants at 16,490 lbs./acre, while Wilson (1941) reports Trout Lake, Vilas County, at 6,650 lbs./acre and Fraser (unpublished) found only 510 lbs./acre in Weber Lake, Vilas County.

Lundbeck (1927) showed the importance of aquatic plants in furnishing food for fish when he studied the fish food of central European ponds. He reported that the naked bottom carried a population of 6.28 gm. of organisms per sq. m.; the submerged aquatics, 6.41 gm. per sq. m.; and the emergent plants, 8.29 gm. per sq. m. Schiemenz (1927) also indicated the importance of pond weeds as measures of productive waters. He claimed the following species were most valuable as indicators of productive waters: *Potamogeton* sp., *Myriophyllum* sp., *Elodea canadensis*, *Ranunculus aquatilis* and *Polygonum amphibium*.

Needham (1928) in a study of New York streams pointed out that plant beds are 37 times as rich in trout foods as bare pool bottoms and 7 times as rich as bare stream beds. More recently Frohne (1938) has worked out the life histories of several insects inhabiting plants and Krecker (1939) has found a difference in the productivity of different species of lake plants.

The animal populations are fluctuating hourly by natural die off, emergence of maturing insects, predation from fish and other animals. Moreover, the plant populations are sporadic in their distribution in addition to undergoing succession through the summer; consequently it is difficult to locate any two square meters which are of identical plant composition in species as well as quantity. Still another obstacle to the biologist who wishes to estimate the population is the mechanical chore of removing completely all of the animals from the plant for enumeration and weighing. In view of these variables in the littoral habitat it is difficult to secure data that can be taken as truly characterizing such a habitat.

## METHODS

*Sampling of plant associations:*

A net was devised which would effectively trap all of the macroscopic invertebrate animals over a given unit of bottom together with the plants on which they were living. The first net constructed had a mouth area of one square meter; later another with a mouth area of ½ sq. m. was constructed. Canvas was at first used for the main part of the net, but sharkskin cloth was found to be lighter and more serviceable, so the second net was constructed of this material. The net was so made that it could be lowered with the mouth opened over ½ sq. m. of plant habitat and enclose the plants and all the animal life on them or in the water between them. A zipper opening in the side of the net allowed the insertion of the hand to uproot the plants enclosed. The mouth of the net was then securely closed, and the net with its contents removed from the water. A bolting-cloth straining net at the end away from the mouth allowed the water to be quickly strained out leaving the plants and their inhabitants in the bolting-cloth tip. These were then removed and washed off into pails and taken to the laboratory for counting and weighing.

An aliquot of strainings and plant material was measured from the large sample, carefully picked over, the animals removed, enumerated, then weighed moist and after oven drying at 60° C. Also the plants clean of animals were weighed moist and oven dry. It is easy to see that this procedure is so time consuming and painstaking that large numbers of samples cannot be included by a single worker.

An effort was made to take samples within a definite area—that is, within a radius of 25 feet of a buoy which marked the collecting site. We found that in a given area the relative abundance of the different species of plants changed during the summer—there was a seasonal plant succession. This made impossible seasonal comparisons of the animal populations of a mixed plant habitat.

*Estimation of small fish population*:

A 175 foot net 6 feet deep of ¼ inch mesh was used to seine an area of 7500 square feet. Stakes were placed around the area and the seine pulled inside. Two hawls were made over different areas along the shore of Picnic Point on each seining day.

## RESULTS

*Species productivity*:

The work in 1939 indicated that those plants with the most dissected surface area harbor the largest population of animals.

They can be grouped as follows:

| | | |
|---|---|---|
| Most productive | *Ceratophyllum demersum* (coontail) | 52,000 animals per kg. of plant |
| | *Myriophyllum exalbescens* (water milfoil) | 29,000 " " |
| Moderately productive | *Potamogeton pectinatus* | 21,000 " " |
| | *Chara sp.* | 17-20,000 " " |
| Less productive | *Potamogeton americanus* | 18,000 " " |
| | " *Richardsonii* | 10,000 " " |
| | " *amplifolius* | 5,000 " " |
| Poorly productive | *Vallisneria americana* | 3,000 " " |

The figures in Table Ia give the numbers of the most common animals found on each kind of plant and expressed as number of animals per kg. of plant. The data are the mean of 17 samples made in 1939. The most numerous organisms on all plants are chironomids and *Hyalella* (scuds) and they are more numerous on *Ceratophyllum* and *Myriophyllum* than on other species of plants and therefore substantiate the claim that plants with the most highly dissected leaves are the most productive.

*Chronology of some biological events in University Bay in 1941:*

April 24. Temp. 6° C. Most of bottom in littoral area bare. *Potamogeton praelongus* found growing from the winter buds in the axils of old leaves. Old leaves brown.
*Chara* overwintered and beginning to get green. Many thick beds of *Chara* found inside the bar of University Bay.

April 26. Temp. 7° C. *Potamogeton praelongus* found with long shoots a foot long. Very rapid growth. Leaves of *P. amplifolius* quite brown—no new leaves. *P. pectinatus* present in sand, but not green. *P. americanus* showed some winter buds shooting new spikes. *Myriophyllum* showed new shoots 6 inches long. Bowfins were spawning.

May 3. *Scirpus* arising from sand in new shoots.
Emergence of many damsel flies and mayflies.

May 10. Temp. 19° . Hundreds of spiraled egg masses of perch.
*Myriophyllum*—pure stands 8 inches high.
No *Chara* on the bar yet, but on either side a considerable quantity had overwintered although still brown.

Carp spawning in shallow water among *Cladophora* on shore. *Cladophora* abundant.
Many large black bass observed.
*Scirpus* had reached water level (8")—many chewed by muskrats.
*Ranunculus trichophyllus* plants seen inside bar (distinguished by numerous white rootlets growing from each internode).

May 15. Temp. 15° C. Perch eggs rare—many old masses decomposing. One bass observed building nest.

June 16. Temp. 20° C. *Scripus acutus* flowering.
Many limpets on stocks of bulrush.
*P. praelongus* has flowering spikes at surface.
*P. Richardsonii* plants are now present.

*Microscopic invertebrate animals on mixed plant associations*:

The introduction and discussion of this paper point to the several kinds of variables that may influence observations of this kind. Nevertheless, since the methods of sampling enumeration and weighing were constant within the limits of human error we submit the following results in full awareness of the variables that are natural and out of control. However, it should be kept in mind that all limnological and ecological observations of aquatic populations are also subject to most of these variables.

The 1940 results on mixed plants (Table I) are the mean of 16 collections. *Hyalella*, a small amphipod, was the dominant organism in both numbers and weight. We observed them occurring in numbers as great as 1590 per sq. m. of bottom, or if computed on the basis of plant weight they may be as abundant as 25,200 per kilogram of dry plant. The latter figure requires some qualifications since the dry weight of plants (see discussion of *Chara*) increases with the season due to heavy depositions of lime on the leaves and stems.

Table I also shows the estimates of the total quantity of animals in this narrow plant zone along the south shore of Picnic Point in an area approximately 100 ft. wide, or that region extending from the 2 foot contour to the 6 foot contour. This area, as estimated from our series of samples, produces at least 81 kilograms/hectare (72 lbs./acre) of macroscopic organisms (exclusive of fish). We use the qualification "at least" since we

TABLE Ia. No. of animals per kg. of dry plant in 1939.

| | Hydrachnids | Chironomids | Mayflies | Caddisflies | Hyalella | Oligochaetes |
|---|---|---|---|---|---|---|
| Vallisneria | 202 | 674 | 374 | 179 | 271 | 91 |
| Ceratophyllum | 1450 | 9860 | 1078 | 1880 | 23150 | 316 |
| Myriophyllum | 3800 | 2795 | 6950 | 2430 | 10800 | 870 |
| P. pectinatus | 233 | 4220 | 2350 | 967 | 14200 | 348 |
| P. Richardsonii | 516 | 2705 | 688 | 425 | 5860 | — |
| P. amplifolius | 303 | 2275 | — | 758 | 758 | 151 |
| Chara | 504 | 926 | 534 | 720 | 8540 | 410 |
| P. americanus | — | 2425 | 485 | 970 | 485 | — |

TABLE Ib. Population of macroscopic invertebrates on mixed plant populations.

| | June | July | August | No. samples | Mean |
|---|---|---|---|---|---|
| *Total weight of organisms:* | | | | | |
| Dry wt. mg./sq.m. | 1000 | 630 | 770 | 15 | 810 |
| Wet wt. lbs./acre | 89.2 | 56.1 | 68.5 | 15 | 72.0 |
| Wet wt. kg./ha. | 100 | 63 | 77 | 15 | 81 |
| *Dry weight of org. in mg./sq.m.:* | | | | | |
| Hydrachnids | 180 | 40 | 30 | 15 | 80 |
| Chironomids | 70 | 140 | 30 | 15 | 90 |
| Mayflies | 50 | 70 | 70 | 15 | 70 |
| Hyalella | 310 | 230 | 220 | 15 | 250 |
| *Number of org./sq.m.:* | | | | | |
| Hydrachnids | 163 | 146 | 90 | 15 | 138 |
| Chironomids | 760 | 750 | 138 | 15 | 595 |
| Mayflies | 250 | 63 | 359 | 15 | 192 |
| Hyalella | 500 | 1590 | 1883 | 15 | 1000 |

feel the figure would be, if anything, an under-estimation due to personal errors in the picking procedures.

*Macroscopic invertebrates on Chara:*

In 1940 it became apparent that some natural variables could be reduced by restricting the study to a plant which occurred in a pure stand. *Chara* was found to do so.

Table II gives the summary for the 1940 and 1941 collections. No correlation can be seen from the numbers of animals during the same month in either year. On the other hand the mean weight of the organisms per unit area is surprisingly consistent. It seems likely that a given area produces a similar weight of organisms from year to year. At least this has been observed many times in fish culture and stock raising where it has been determined that a given area of water or land will produce a maximum poundage of meat; this total weight may be in large numbers of small animals or small numbers of large animals.

TABLE IIa. Population of invertebrate animals on *Chara*.

| | June | July | August | September | No. samples | Mean |
|---|---|---|---|---|---|---|
| MAYFLIES | | | | | | |
| *No. org./sq.m.* | | | | | | |
| 1940 | — | 55 | 1230 | 1170 | 10 | 890 |
| 1941 | 150 | 546 | 261 | 392 | 20 | 360 |
| *Dry wt. in mg./sq.m.* | | | | | | |
| 1940 | — | 40 | 52 | 90 | 10 | 55 |
| 1941 | 90 | 70 | 47 | 26 | 20 | 51 |
| HYALELLA | | | | | | |
| *No. org./sq.m.* | | | | | | |
| 1940 | — | 3615 | 7830 | 11070 | 10 | 6480 |
| 1941 | 1880 | 2844 | 5720 | 10420 | 20 | 6100 |
| *Dry wt. in mg./sq.m.* | | | | | | |
| 1940 | — | 339 | 556 | 770 | 10 | 440 |
| 1941 | 700 | 310 | 480 | 870 | 20 | 550 |

TABLE IIb. Total organisms on *Chara*.

| | | | | | | |
|---|---|---|---|---|---|---|
| *No. org./sq.m.* | | | | | | |
| 1940 | — | 4730 | 9150 | 11450 | 10 | 7548 |
| 1941 | 2825 | 4253 | 6441 | 10698 | 20 | 6593 |
| *Dry wt. in mg./sq.m.* | | | | | | |
| 1940 | — | 430 | 600 | 950 | 10 | 600 |
| 1941 | 1090 | 460 | 630 | 1160 | 20 | 760 |
| *Wet wt. kg./ha.* | | | | | | |
| 1940 | — | 43 | 60 | 95 | 10 | 60 |
| 1941 | 109 | 46 | 63 | 116 | 20 | 76 |
| *Wet wt. lb./acre* | | | | | | |
| 1940 | — | 38.3 | 53.6 | 84.6 | 10 | 53.5 |
| 1941 | 97.2 | 41.0 | 56.2 | 103.5 | 20 | 67.8 |

The mean dry weight of mayflies was 55 mg./sq. m. in 1940 and 51 mg./sq. m. in 1941. For *Hyalella* it was 440 mg./sq. m. in 1940 and 550 mg./sq. m. in 1941. The total population weighed 600 mg./sq. m. in 1940 and 760 mg./sq. m. in 1941. When this is converted to kilograms per hectare (net weight) the figures are: 60 kg/ha., (53.5 lbs./acre) in 1940 and 76 lbs./ha. (67.8 lbs./acre) in 1941.

*Hyalella* was the dominant organism in both years. It occurred in twice the amount on *Chara* as it did on the mixed plant populations. This shows that *Chara* is well suited for these races of amphipod.

TABLE III. Population of fingerling and fry of game and pan fish in plant zone.

| | Perch All sizes | Fry and Fingerling Centrarchids | Fry and Fingerling Pickerel | Minnows | No. of Hauls |
|---|---|---|---|---|---|
| *Number per acre:* | | | | | |
| 1939 | 1608 | 1321 | 12 | 220 | 5 |
| 1940 | 1133 | 50 | 29 | 16 | 13 |
| 1941 | 1220 | 57 | 14 | 0 | 12 |
| *Number per hectare:* | | | | | |
| 1939 | 3973 | 3278 | 30 | 543 | |
| 1940 | 2798 | 125 | 71 | 39 | |
| 1941 | 3060 | 144 | 34 | 0 | |
| *Wet wt. in lbs./acre:* | | | | | |
| 1939 | 117 | | | | |
| 1940 | 79 | | | | |
| 1941 | 88 | | | | |

The dry weight of *Chara* increased appreciably as the summer progressed. In June the average per cent dry weight of *Chara* was 17.2% in July, 19.0%, and in August, 25.1%. *Chara* actively extracts $CO_2$ from the carbonates of the water and deposits lime on its surface.

It is noteworthy that in 1940 *Chara* produced 60 kg./ha. of macroscopic invertebrates as compared with 81 kg./ha. for a mixed plant population. In other words, *Chara* is about 75% as efficient in the production of fish food in a pure stand (one species) as a mixed plant stand.

*Small fish populations:*

Table III presents the mean population of fingerling and fry game and pan fish that inhabit the aquatic plant zone studied in the region described above.

There is a sharp reduction in the numbers of centrarchids (bass family) after 1939 due chiefly to a smaller hatch of blue gills in 1940 and 1941 as compared with 1939. The number of perch was lower in 1940 than 1939 to which we attribute chiefly a heavy mortality resulting from an epizootic of *Myxobolus* (a sporozoan) among the older perch late in 1939.

Since we caught consistently large numbers of perch in every hawl made, we feel the data from them can be a fairly accurate computation of the total yield of perch in this area. Our calculations based on hawls with a ¼ inch mesh minnow seine pulled over an area 7500 sq. ft., are seen in Table III.

## Discussion

It must be kept in mind that a study of a natural mixed invertebrate population is exceedingly difficult—the variety of changes taking place every hour make impossible an accurate measure of their population density. Some of these factors which alter the density are:

1. Predation by fish.
2. Predation by larger invertebrates, snakes, turtles, amphibia and birds.
3. Periodic emergence of insect naiads and pupae.
4. Irregular density of plants and irregular distribution of species of plants so that no one square meter of bottom is identical with any other.
5. Succession of one plant population to another throughout the summer so that one grouping of mixed plants is the same from month to month.
6. Fluctuations in food supply of microscopic organisms upon which the macroscopic invertebrates feed.
7. Appearance of new broods.
8. Occurrence of races of individuals of the same species but of different size.

This list of variables with the small number of collections that were possible tends, of course, to reduce somewhat the validity of the figures as representing the usual state of affairs in the environment studied. Nevertheless we offer these observations as an attempt at a quantitative study and trust that they will be a guide to our future work and that of other aquatic ecologists.

There is a rough correlation between our findings and those of Krecker (loc. cit.) on the relative productivity of various plant species (the greater the dissected leaf surface the more productive the plant) in spite of the different method of measurement. Krecker reported his results as number of animals per 10 linear feet of plant stem.

We are not convinced that our method of reporting comparative productivity in gm./kg. of plant, is superior to Krecker's. The chief criticism we have of our method is that early summer weights are not comparable to late summer weights because the dry weight of the plant increases as a result of the accumulation of carbonate. If the ash weight of the plants were made, however, the comparison would be accurate.

We observed a dominance of amphipods on *Chara* as did Needham (loc. cit.) on streams where he reported 61% of the animals on *Chara* were *Gammarus*. However, there is a great discrepancy in the total production in the two habitats. He reported 377 gm. of org./sq. m. on stream *Chara* where we found at most 7.6 gm./sq. m. (wet weight) on *Chara* in lakes.

We are in closer agreement with Lundbeck (loc. cit.) on the productivity of mixed submerged plants. He found 6.28 gm. of organisms per sq. m. of pond where we measured an average of 8.1 gm./sq. m. of littoral bottom.

It is surprising that the 1940 weight of the mixed plant "standing crop" of macroscopic invertebrates is smaller than the weight of the small fish in the littoral zone. Fish culturists estimate that it takes 5 lbs. of food to make a pound of fish. If this be true then on the face of the figures there is about ⅛ of the food requirements to be found on the plants. Yet we know that the rapid replacement rate of the small food animals is considerable—but since the individual species life cycles are unknown it cannot be estimated even roughly. Suffice it to say that since the weight of the fish is an accumulative one, the invertebrate fauna is a frequently replaced one therefore they must furnish considerably more than ⅕ of the food requirements. Moreover, there are other sources of food for the small fish such as the littoral plankton crustacea and rotifers and perhaps some bottom organisms in addition to food from cannibalism. The quantity of these foods has not been measured for the littoral zone.

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# MICROMONOSPORA IN RELATION TO SOME WISCONSIN LAKES AND LAKE POPULATIONS*

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## INTRODUCTION

There are a number of reports of bacterial studies of single lakes and groups of lakes in regard to the total organisms present. Occasional studies have been made of specific groups of organisms of allied physiological activity, for example, urea decomposers, sulfate reducers, cellulose decomposers, nitrifiers, etc., but there has apparently been no study made of a particular genus in its correlation to the diverse lakes.

In a former study of the bacterial content of Lake Mendota conducted by the Department of Agricultural Bacteriology, it was noted that the dilution plates contained numbers of chromogenic bacteria of the genus *Micromonospora* of the order *Actinomycetales.* The numbers of these organisms were such that it was thought that they possibly played an important role in lacustrine ecology. This is a report of a survey of 12 lakes of the state, together with an intensive study of one lake, in connection with this group of microorganisms.

## THE GENUS *MICROMONOSPORA*

Jensen (1930, 1932) in his investigation of the genus *Micromonospora* Ørskov used the descriptive term "a little known group of soil microorganisms." The organisms are still not well known—a feature that seems to apply to most members of the order *Actinomycetales* as compared with those of the *Eubacteriales.*

In 1923 Ørskov erected the genus and used as the type species *M. chalceae,* an organism formerly known as *Streptothrix chal-*

* This investigation was supported in part by a grant from the Wisconsin Alumni Research Foundation.

*ceae.* The descriptions of this organism are very limited. Foulerton (1905) first isolated it from the air, but there appears to be nothing published by him of it. Musgrave, Clegg, and Polk (1908), authors of a publication on pathogenic actinomycetes, received a culture of Foulerton's but their description, too, is incomplete.

Ørskov described the organisms in the genus as follows: "a branched, unicellular mycelium is formed, consisting of very delicate hyphae with short, lateral branches, each of which bears a single terminal spore. The spores are small, oval, and highly refractive."

In a subsequent work (1938) he emphasized "die terminal einzelsitzenden Sporen" of the organisms as setting the genus apart from the other members of the family *Actinomycetaceae.* In this investigation he emphasized that Jensen's work had clearly proved the validity of the genus.

In 1930 and again in 1932 Jensen published studies of the members of the genus which he had isolated originally from Danish soil and again later from Australian soils. The soils were of a wide range of composition. One, a laterite soil poor in organic matter with a pH of 6.5, gave several isolants as did an alluvial soil of heavy clay which was rich in organic matter and of a pH of 6.0. An Australian soil of a red sandy loam, poor in organic matter with a pH of 6.8 and receiving an annual rainfall of 15.7 inches had the highest percentage of these organisms. Jensen found here that 17.5% of the total actinomycete colonies evidenced by plating were *Micromonospora.* This was a number equal to 472,500 organisms per gram of soil.

Another red sandy loam of the same region, different only in having a pH of 7.9, had a *Micromonospora* count of 4.7% of the actinomycete colonies. Here the total count of the members of this genus was 653,000 organisms per gram of soil. The conclusion made by Jensen was that the *Micromonospora* made up 5 to 8% of the total numbers of the colonies of *Actinomyces*-type. Their appearance was most frequent in neutral to alkaline soils from comparatively dry districts.

Waksman, Umbreit and Cordon (1939), in studying thermophilic actinomycetes and fungi in soils and composts, found thermophilic strains of the *Micromonospora.* Their technique of contact slide culture enabled them to detect three species of the genus. One was isolated in pure culture, but isolation of the other two was not accomplished. All were similar to the mesophilic forms described by Jensen.

The aforementioned three workers, in a review of some of the literature of the thermophilic actinomycete-like organisms found in composts and like substances, have brought out the findings of some of the earlier investigators Miehe (1907), Schütze (1908), Tsiklinsky (1903) who undoubtedly worked with *Micromonospora.* More recent workers with the *Micromonospora* include Erikson (1940) and Harden (1941). Erikson studied 10 strains of *Micromonospora* isolated from Lake Mendota and Trout lake. She found her strains capable of growing on a large variety of more or less resistant organic compounds. Harden noted that these organisms in two lakes—Mendota and Green—were of significant proportions of the total count of the bottom deposits. She found that the *Micromonospora* were similarly high in numbers in the make-up of the characteristic chromogens of the lakes.

## Sample Collection

Three main pieces of apparatus served to secure all the samples of the lake waters and muds. The Wilson (1920) sampler was used for water samples from all depths. Test tubes of 18 mm x 150 mm were used for the samples. At the upper water levels the vacuum was barely adequate to fill the tubes, but at the lower levels the added hydrostatic pressure of the water caused rapid filling of the sample tubes. A trip-recording thermometer was used to secure water temperatures. Readings were made at the time of water samplings except during the period of freeze over.

An Ekman dredge 15 cm x 15 cm x 15 cm, well known to the limnological worker, sufficed in securing bottom samples. It readily removed the sludge-like samples of the profundal areas to a depth of about 15 cm, but when sampling was done in the littoral zones where sand and rotted plant remains were encountered, many trials had to be made before these samples could be taken. All bottom samples, when brought to the surface, were thoroughly mixed and placed in sterile glass jars for transportation to the laboratory.

Henrici and McCoy (1938) devised an apparatus effective in taking cores for a study of the vertical distribution of bacteria in the bottom deposits. In the work mentioned, the force given to the sampler to cause it to penetrate into the mud was gained by a free fall. To give a rifling effect, and thus a vertical descent, vanes were built into the top of the sampler. This meant, of course, that the heavy lead pounding weight could not be used. The sampler they devised was used in this work with the exception of the section diagrammed in their paper as number III. Due to an inability to secure a replacement for this part a modification was made. This modification of the sampler was used in taking the cores from the 18 meter depths of Lake Mendota. A cap with a welded ring, to which was attached a heavy swivel, was screwed onto the part of the section containing the weight. The twisting of the three ropes thus could be avoided and a greater ease of handling the sampler was effected whether it was lowered through a hole in the ice or whether lowered from a boat.

The pounding action of the alternately raised and dropped lead weight drove the sampler into the muck. A winch was used to lift the sampler into the boat when the apparatus was used over free water. Sterile corks inserted into the open ends of the sampler tubes enabled the whole container to be removed to the laboratory for testing. Care was taken in transporting these tubes so that the soft upper parts of the enclosed cores would not be tipped and thus mixed.

Henrici and McCoy utilized glass tubing to remove the samples through the screw holes in the sampler. In this work a change was made from their technique. It was found satisfactory to open successively downward the screw plugs of the vertically held sampler until the first murky ooze came out. At this time a sterile, tightly fitting cork was inserted in the top of the sampler, backed by sterile cotton and then, by means of a plunger, the whole "wurst-like" sample was forced out in a single piece onto sterile paper. With sterile spatulas the core was opened and samples at desired depth secured.

## Cultural Methods

Four different media were tried before one was selected as standard for the study of the group. For one medium an extract of the bottom mud was made by steaming a one to one dilution of mud in lake water and then allowing the mass to settle. The supernatant fluid was siphoned off and agar at the rate 1.2% was added. The medium was discarded as unsuitable as the isolation medium, since the total count of microorganisms which developed on it was low. Too, there was an undesirable darkness to the medium, and, of more importance, the decided chromogenesis of the *Micromonospora* failed to develop. As a result identification of the organisms was made more difficult.

The dextrose-casein agar medium used by Jensen (1930) for isolation of his soil forms failed to give the desired chromogenesis and colonial size. The medium was very clear, and although it was not used for the isolation of the *Micromonospora* from the lake samples, in subsequent pure culture studies it served admirably.

The nutrose medium used by Henrici and McCoy (1938), a modification of the Nährstoff Heyden type agar medium so frequently utilized in soil bacteriological studies and in many lake studies—Allgeier, Peterson, Juday and Birge (1932), Graham and Young (1934), Williams and McCoy (1935), Carpenter (1939), ZoBell and Stadler (1939)—was originally used. However, because of the spreading colonies developing during the lengthy incubation period, it was discarded in favor of the starch-casein medium. This medium was the same as that used by Jensen in his work on this group. Its composition is simple: 10 grams of soluble starch, 1 gram of casein dissolved in N NaOH, 0.5 gram of $K_2HPO_4$, 0.5 gram of $MgSO_4$ were made up to 1 liter with Lake Mendota water. Agar at the rate of 1.2% gave satisfactory solidity to the bottle plate. The pH of the medium was adjusted to 7.4. With this medium, unless the casein is thoroughly macerated in the N NaOH, there is an undesirable coagulation upon autoclaving. The longer the interaction between the casein and the NaOH is allowed to take place before bottling and autoclaving, the clearer is the resulting medium.

Dilution plate counts were used in the investigation. Replicates of eight bottle plates were made in bottom mud tests; replicates of 3 or 5 bottles were used when plating the overlying waters of the lakes.

To secure an adequate sample of the well-mixed muds, 25 gram portions were used to make the first dilutions. Each dilution sample was agitated a uniform 100 times prior to the next dilution. Since the sludge deposits of lakes are recognized to have strong adhesive forces, it was felt the vigorous agitation was needed to free the microorganisms from the mud particles.

ZoBell and Conn (1940) have clearly shown the effect of even moderate heating upon water bacteria. To minimize the deleterious effect upon the microorganisms by the slow cooling of the agar subsequent to the pouring of the bottle plates, the warm bottles were placed upon iced toweling to facilitate cooling.

Incubation of the bottles was at room temperature for from 25 to 30 days. Reading of the plates was made over a lighted counting box equipped with a magnifying glass. The colonies of bacteria developing on the plates were counted and their average appears in the tables as total count. Each plate also had the total number of pigment-bearing colonies recorded. It is the average of these which are termed chromogens in the following tables.

The identification of a *Micromonospora* colony is difficult (this was the main reason their presence among the organisms found in the lakes was over-looked so long). The recognition of the surface colonies is aided by their black spore crust (however, the degree of sporulation to form this crust varies), by the lavender, orange, salmon, rust or pink color of their mycelium and by the appearance of the "make-up" of the colony as is shown by its enlargement under the magnifying glass of the colony counter.

Often the colonies grew under the surface of the agar and their identification was made uncertain by their failure to develop the typical spore crusts; such colonies were picked from the plates for further identification tests. *Actinomyces* and *Micromonospora* colonies are hard and quite leathery; hence the ordinary laboratory nichrome inoculation needle and loop are not strong enough to handle embedded colonies. Thus when it was necessary to remove the colony from the dilution plates, the whole colony was removed aseptically by a loop made especially stiff in the shank by the twisting together of a doubled nichrome wire. This strengthened shank was bent at the loop end into such a shape that the loop could be pressed into the agar and remove the whole agar-embedded colony to a tube of nutrose broth. To free the colony from the agar and thus facilitate growth in the new medium, the agar block was macerated against the inner wall of the tube of broth by another shaft-strengthened nichrome wire unit. It was found that if the end of this shaft was flattened into a spatula shape, the crushing of the hard, tenacious colonies was made easier.

Nutrose broth is normally "milky" in appearance. Actinomycete-like organisms which have been encountered when growing in such broth exhibit two growth characteristics: one, the "milky" broth is cleared and, two, the organisms settle to the bottom of the tube in balls or clumps or, less frequently, grow attached to the sides of the tube in feather-like clumps.

Since the members of the genus *Actinomyces* encountered in lake studies react in the same fashion as do the *Micromonospora* as described above, a further procedure is necessary for a division of the *Micromonospora* from the *Actinomyces*. To accomplish this, a portion of the growth was transferred to slants of starch-casein agar and were incubated at room temperature. After 10 to 15 days most of the *Micromonospora* had produced a spore crust which permitted them to be identified by microscopic examination. The *Actinomyces* also produced their characteristic aerial spores which facilitated their identification. In a few instances where neither the spore crusts of the *Micromonospora* nor the aerial spores of the *Actinomyces* were evident, slide cultures of dextrose-casein agar were prepared. Thus it was possible to make the final decision of the grouping of the organism as a member of the genus *Micromonospora*. In some cases no spores were ever evident; the researches of Umbreit (1939) offer the possibility that such organisms may be members of the beta group of the genus *Proactinomyces*.

## Results

The morphological, chemical and physical differences between those lakes of the Northeastern area, centered about the Trout Lake Laboratory, and the Southern lakes near the University laboratores are marked. The voluminous records of the Limnological Laboratory of the Wisconsin Geological and Natural History Survey served as a source of information for Table

TABLE I. Some morphometrical, physical and chemical data on the lakes tested for bacterial content. The material has been collected from reports of the Wisconsin Natural History Survey. The organic matter of the bottom deposits was calculated by doubling the organic carbon content.

| Lake | Type | Type of bottom deposits | Hectares of surface area | Depth Max. | meters Mean | pH | Ca mg/1 | Bound $CO_2$ mg/1 range | Organic matter of bottom deposits |
|---|---|---|---|---|---|---|---|---|---|
| Crystal | oligotrophic | gyttja | 30.2 | 21.0 | 9.6 | 5.0-9.6 | .84 | 0.3- 2.5 | 51.2 |
| Little John | low eutrophic | gyttja | 67.2 | 6.0 | 3.7 | 7.5 | 14.0 | 17.8 | 58.7 |
| Muskellunge | low eutrophic | gyttja | 372.3 | 20.7 | 7.0 | 6.1-8.4 | 6.2 | 8.6-17.5 | 56.3 |
| Nebish | low eutrophic | gyttja | 38.4 | 15.8 | 5.2 | 5.9-7.5 | 2.5 | 2.8-13.4 | 56.2 |
| Trout | oligotrophic | gyttja | 1,583.4 | 35.0 | 13.7 | 6.5-8.2 | 11.9 | 13.7-21.7 | 40.4 |
| Weber | oligotrophic | gyttja | 15.6 | 13.5 | 7.2 | 5.1-6.9 | .68 | 0.5- 4.5 | 44.6 |
| White Sand | low eutrophic | gyttja | 216.1 | 21.0 | 8.9 | 6.8 | 9.6 | 15.1 | 41.0 |
| Koshkonong | eutrophic | kalkgyttja | — | — | — | — | — | — | — |
| Mendota | high eutrophic | kalkgyttja | 3,939.2 | 25.6 | 12.1 | 7.2-8.8 | 23.3 | 72 -80 | 14.1 |
| Monona | eutrophic | kalkgyttja | 1,410. | 22.5 | 8.4 | — | — | 74 | 13.0 |
| Ripley | eutrophic | kalkgyttja | 187.2 | — | — | — | — | — | — |
| Waubesa | eutrophic | kalkgyttja | 824. | 11.1 | 4.9 | — | — | — | — |
| Wingra | eutrophic | kalkgyttja | 80.9 | 4.2 | 1.6 | 7.8-8.7 | — | 85 -90 | — |

TABLE II. The summary of the bacterial population of the bottom deposits of 12 Wisconsin lakes (wet basis).

| Lake | Depth | Date | Total count | Chromogens | *Micromonospora* | *Actinomyces* | % Chromogens of Total count | % *Micromonospora* of Total count | % *Micromonospora* of Chromogens | % *Actinomyces* of Total Count |
|---|---|---|---|---|---|---|---|---|---|---|
| Ripley | 6 meters | 9-10-41 | 197,000 | 50,000 | 30,000 | 12,000 | 25.3 | 15.2 | 60.0 | 6.0 |
| " | 12.0 " | " | 585,000 | 147,000 | 65,000 | 52,000 | 25.1 | 11.1 | 44.2 | 8.8 |
| Waubesa | 2.0 " | 11-16-41 | 720,000 | 270,000 | 15,000 | 21,000 | 37.5 | 2.0 | 5.5 | 2.9 |
| " | 4.5 " | " | 498,000 | 120,000 | 22,500 | 30,000 | 24.0 | 4.5 | 18.7 | 6.0 |
| " | 7.0 " | " | 1,140,000 | 375,000 | 39,000 | 45,000 | 32.8 | 3.4 | 10.4 | 3.9 |
| Monona | 4.0 " | 2-24-42 | 56,800 | 4,800 | 400 | 800 | 8.4 | <1.0 | 8.3 | 1.4 |
| Wingra | 2.0 " | 8-18-42 | 716,000 | 205,000 | 68,000 | 21,000 | 28.6 | 9.4 | 33.1 | 2.9 |
| Koshkonong | 2.0 " | 9-10-41 | 5,670,000 | 1,190,000 | 0 | 140,000 | 20.9 | — | — | 2.4 |
| Weber | 13.5 " | 7- 3-42 | 147,600 | 13,300 | 300 | 0 | 9.0 | <1.0 | 2.2 | — |
| Crystal | 21.0 " | 8- 5-42 | 65,200 | 2,000 | 500 | 0 | 3.0 | <1.0 | 25.0 | — |
| Little John | 5.5 " | 8- 5-42 | 102,300 | 22,000 | 5,600 | 1,000 | 21.5 | 5.4 | 25.4 | <1 |
| Nebish | 6.0 " | 7-16-42 | 94,000 | 18,200 | 0 | 0 | 19.3 | — | — | — |
| Muskellunge | 14.0 " | 8-26-42 | 241,000 | 52,500 | 5,500 | 4,000 | 21.7 | 2.2 | 10.4 | 1.6 |
| White Sand | 9.0 " | 7-19-41 | 60,000 | 13,300 | 6,000 | — | 22.1 | 10.0 | 45.1 | — |
| Trout, South | 9.0 " | 7-19-41 | 23,300 | 6,000 | 6,000 | — | 25.7 | 25.7 | 100.0 | — |
| " " | 18.0 " | 7-19-41 | 620,000 | 50,000 | 15,000 | — | 8.0 | 2.4 | 30.0 | — |
| " " | 30.0 " | 8-11-41 | 256,000 | 86,000 | 86,000 | — | 33.5 | 33.5 | 100.0 | — |
| Trout, North | 11.0 " | 7-19-41 | 45,000 | 10,000 | 10,000 | — | 22.2 | 22.2 | 100.0 | — |
| " " | 29.0 " | 7-19-41 | 390,000 | 30,000 | 10,000 | — | 7.6 | 2.5 | 33.3 | — |

I. Many more items of interest might have been included but those given in the table show factors that well might affect the life in the lake.

The results of the survey of the bacterial flora of seven of the lakes of the Northeastern part of the state together with five of those of the Southeastern section are summarized in Table II. The results of the work on Lake Mendota, a member of the latter group, is omitted from this table because of the more extensive reports to be presented later in this paper.

With the exception of Koshkonong and Nebish all the lakes sampled indicated the presence of *Micromonospora* in their bottom deposits. In the case of Lake Koshkonong, since weather conditions made it impossible to sample in the deepest portions of the lake, test portions were secured only of the southern end where the lake narrowed into Rock river. With the exception of Lake Mendota, Koshkonong had the highest counts of bacteria found in the survey. Two testing periods of Nebish failed to detect the *Micromonospora* in its bottom deposits. One sampling was made in August 1941 and the second was made in July 1942. The results of the July sampling are shown.

Of the 18 samplings recorded in Table II it is interesting to note that but six of them showed less than 20% of the total count to be chromogens. This is in agreement with the findings of other workers—Fred, Wilson and Davenport (1924), Snow and Fred (1926), Graham and Young (1934), Williams and McCoy (1935), Henrici and McCoy (1938)—who have noted the high number of these pigment-bearing organisms in lake bacterial counts. A point of major interest is the marked range of the *Micromonospora* which is shown to be from 100% in the case of some Trout lake samples to a low of 5.5% in Lake Waubesa—a lake of unusual water content due to sewage effluent from the city of Madison.

Of the northern lakes Trout showed the highest count of *Micromonospora*—86,000 of these organisms per gram wet weight of bottom deposit. The southern lakes were consistently higher in these organisms. It also may be seen that the total count of bacteria in the bottom deposits of the northern lakes are much lower than those of the southern bodies of water. This corresponds to the findings of Carpenter (1939) who worked on the northern lakes near the limnological station at Trout lake.

TABLE III. Bacterial counts of bottom deposits from bay, littoral and sub-profundal areas of Lake Mendota.

| Areas Tested | Depth in meters | Date | Total Count | Chromogens | *Micromonospora* | *Actinomyces* | % Chromogens of Total count | % *Micromonospora* Total count | % *Micromonospora* Chromogens | % *Actinomyces* of Total Count |
|---|---|---|---|---|---|---|---|---|---|---|
| Bay and Littoral | 2.0 to 3.5 m | 6-16-41 | 356,000 | 63,000 | 3,300 | <1,000 | 17.6 | < 1.0 | 5.2 | — |
| | | 8-26-41 | 161,000 | 33,000 | 3,000 | — | 20.4 | 1.8 | 9.0 | — |
| | | 2-20-42 | 481,000 | 68,000 | 5,000 | 5,000 | 14.1 | 1.0 | 7.3 | 7.3 |
| | | 5-16-42 | 2,136,000 | 498,000 | 4,000 | — | 23.3 | < 1.0 | < 1.0 | — |
| | | 5-29-42 | 425,000 | 55,000 | 0 | 3,000 | 12.9 | 0 | 0 | < 1.0 |
| 6.5 to 10.0 m zone | 10.0 m | 9- 3-41 | 40,500 | 8,300 | 4,700 | 2,300 | 20.4 | 11.6 | 56.6 | 5.6 |
| | 6.5 m | 9-17-41 | 87,000 | 10,000 | 2,200 | — | 11.4 | 2.5 | 22.2 | — |
| | 9.5 m | 11-22-41 | 98,000 | 23,000 | 1,000 | 5,000 | 23.5 | 1.0 | 4.3 | 5.1 |
| | 10.0 m | 12-13-41 | 106,700 | 17,000 | 2,500 | 1,500 | 15.9 | 2.3 | 14.7 | 1.4 |
| 13.0 to 15.0 m zone | 13.0 m | 9- 3-41 | 432,000 | 153,000 | 10,200 | 3,600 | 35.4 | 2.3 | 6.6 | < 1.0 |
| | 13.5 m | 9-17-41 | 651,000 | 165,000 | 75,000 | 15,000 | 25.3 | 11.5 | 45.4 | 2.3 |
| | 13.0 m | 10-20-41 | 594,000 | 204,000 | 90,000 | 30,000 | 34.3 | 15.1 | 44.1 | 5.0 |
| | 14.5 m | 10-20-41 | 900,000 | 318,000 | 39,000 | 69,000 | 35.3 | 4.3 | 12.6 | 7.6 |
| | 13.5 m | 11- 3-41 | 399,000 | 168,000 | 78,000 | 30,000 | 42.1 | 19.5 | 46.4 | 7.5 |
| | 14.0 m | 11-22-41 | 414,000 | 168,000 | 24,000 | 96,000 | 40.5 | 5.7 | 14.2 | 23.1 |
| | 15.0 m | 12-13-41 | 699,000 | 165,000 | 39,000 | 48,000 | 23.6 | 5.5 | 23.6 | 6.8 |
| | 13.5 m | 4-24-42 | 910,000 | 160,000 | 85,000 | 35,000 | 17.5 | 9.3 | 53.1 | 3.8 |
| | 15.0 m | 4-24-42 | 1,215,000 | 250,000 | 90,000 | 105,000 | 20.5 | 7.4 | 36.0 | 8.6 |
| | 14.5 m | 5-16-42 | 1,494,000 | 192,000 | 120,000 | 24,000 | 12.8 | 8.0 | 62.5 | 1.6 |
| | 14.5 m | 5-29-42 | 1,419,000 | 200,000 | 70,000 | 20,000 | 14.0 | 4.9 | 35.0 | 1.4 |
| | 14.0 m | 6- 6-42 | 1,000,000 | 180,000 | 30,000 | 26,000 | 18.0 | 3.0 | 16.6 | 2.6 |

Table III indicates the effect of type of bottom deposit upon the bacterial count. As was brought out in a limited way in the summary shown by Table II of the two lakes, Ripley and Waubesa, Table III shows data of a more extensive study of this phase of the problem on a particular lake.

Lake Mendota's University Bay area corresponds in large measure to the areas described by Graham and Young (1934), Henrici and McCoy (1938), Stark and McCoy (1938) in their studies on the bacterial flora of such littoral regions. Here at a depth of 2.0 to 3.5 meters the bottom deposits consisted mainly of sand, gravel, coarse undecomposed plant remains and portions of water plants together with roots. The *Micromonospora* counts were low, although in some cases the total count of the microorganisms was high. The table shows that in the littoral zones the *Micromonospora* counts make up but a small fraction of the total count. This fact is again noticeable in the next area of the lake studied.

The hydrographic map of Mendota shows a depression having a maximum depth of 20 meters approximately 450 meters out in the lake from the south shore, at a point opposite the Washburn Observatory. In the plan of sampling it was desired to test a traverse across an area giving access to different types of deposits. Since the bay area of the lake gave essentially the same bacteriological picture as that given by the sampling of the shore line to the depth of 5.0 to 6.0 meters, those results of the immediate depth next to the shore line are not given.

Out in the lake beginning about 150 meters and extending to approximately 225 meters off-shore, a depth range of 6.5 to 10.0 meters was encountered. Here the littoral zone graded in a transition to profundal depths. Twenhofel (1941) has given an excellent treatment of the bottom deposits encountered in Lake Mendota. In this area the Ekman dredge brought to the surface a greyish-black sludge in which coarse organic materials remained; there were shell fragments, sand and detritus of a flaky appearance. In this area the bacterial count was not greatly different in total numbers or *Micromonospora* count from the numbers found in the bay area. There was the exception, however, that the *Micromonospora* made up a larger percentage of the chromogens in the 6.5 to 10 meter section than was true of the bay section.

The next area of bottom deposits investigated was further out in the lake toward the maximum depth. The appearance of the sludge here was markedly different from that of the deposits closer to shore. This deeper deposit was darker, finer in size of particles, had less shells and sand, and it closely approached the consistency of the deposits found at the deepest area. In this region of 13.0 to 15.0 meter depth a consistent increase in total bacterial numbers, chromogens, *Micromonospora* and *Actinomyces* was noted over the two previously examined areas. The percentage of the chromogens of the total count in the 13.0 to 15.0 meter area was higher than that shown in the bottom samples of the littoral regions. In the littoral areas there was a range from a low of 12.9% to a high of 23.3%; in the 13.0 to 15.0 meter area the values ranged from 12.8% to 42%. No season may be ascribed to have a peak value where the ratio of the chromogens to the total count is a regular occurrence. This peak came in the May 16, 1941 testing in the bay area; in the November 11, 1941 testing for the 6.5 to 10.0 meter section and also in the November testings for the 13.0 to 15.0 meter depth.

The *Micromonospora* count in proportion to the chromogen count varied widely. But again, in the area of the deeper water, there was a consistently higher figure for the percentage of these pigment-bearing organisms to the total chromogenic bacteria than was apparent in the two shallower regions. For example, the average percentage for the shallow regions was 13% while in the transition zone the percentage had increased to 36%.

A summary of a year's sampling of the bottom deposits of the 18 meter depression is given in Table IV.

The first sampling of this cycle recorded was that of May 3, 1941. At this period the lake had had its vernal overturn. The researches of Birge and Juday (1911, 1922) bear evidence to the marked effects of this stage in the yearly cycle upon the life of the lake.

The temperature relation of the lake at this time would approximate that shown in Chart 3 under May 16, 1942. This first sampling, together with the second one, revealed the largest numbers of the *Micromonospora* shown during the complete sampling cycle of this profundal area.

As the sampling was carried on into June and July the total

TABLE IV. A bacterial study of bottom deposits at the 18 meter station during the yearly cycle of Lake Mendota—a eutrophic lake. The numbers are given as organisms per gram wet weight.

| Lake condition at time of sampling. | Date | Total count | Chromogens | *Micromonospora* | *Actinomyces* | % Chromogens of Total count | % *Micromonospora* Total count | % *Micromonospora* Chromogens | % *Actinomyces* of Total count |
|---|---|---|---|---|---|---|---|---|---|
| Time of vernal overturn | 5- 3-41 | 1,365,000 | 785,000 | 450,000 | 75,000 | 57.5 | 32.9 | 57.3 | 5.4 |
| | 5-15-41 | 2,455,000 | 925,000 | 465,000 | — | 37.6 | 18.9 | 50.2 | — |
| | 5-28-41 | 1,020,000 | 486,000 | 438,000 | — | 47.6 | 42.9 | 90.1 | — |
| | 6- 4-41 | 680,000 | 390,000 | 330,000 | — | 57.3 | 48.5 | 84.6 | — |
| Partial stratification | 6-16-41 | 990,000 | 410,000 | 355,000 | — | 41.4 | 35.8 | 86.5 | — |
| | 6-23-41 | 1,675,000 | 885,000 | 250,000 | — | 52.8 | 14.8 | 28.2 | — |
| | 6-30-41 | 1,200,000 | 460,000 | 320,000 | — | 38.3 | 26.6 | 69.5 | — |
| Summer stagnation | 7- 8-41 | 940,000 | 315,000 | 300,000 | 15,000 | 33.5 | 31.9 | 95.2 | 1.5 |
| | 8-26-41 | 985,000 | 410,000 | 320,000 | 90,000 | 41.6 | 32.4 | 78.0 | 9.1 |
| | 9- 3-41 | 655,000 | 225,000 | 215,000 | 60,000 | 34.3 | 32.8 | 95.5 | 9.1 |
| | 9-17-41 | 1,000,000 | 335,000 | 225,000 | 75,000 | 33.5 | 22.5 | 67.1 | 7.5 |
| Time of autumnal overturn | 10-20-41 | 830,000 | 330,000 | 150,000 | 80,000 | 39.7 | 18.0 | 45.4 | 9.6 |
| | 11- 3-41 | 725,000 | 310,000 | 175,000 | 75,000 | 42.7 | 24.1 | 56.4 | 10.3 |
| | 11-22-41 | 985,000 | 450,000 | 135,000 | 125,000 | 45.6 | 13.7 | 30.0 | 12.6 |
| Ice forming on lake | 12-13-41 | 2,010,000 | 440,000 | 100,000 | 180,000 | 21.8 | 4.9 | 22.7 | 8.9 |
| First sample through ice | 1-13-42 | 2,070,000 | 640,000 | 120,000 | 140,000 | 30.9 | 5.7 | 18.7 | 6.7 |
| Sample taken through ice | 2- 6-42 | 760,000 | 340,000 | 130,000 | 180,000 | 44.7 | 17.1 | 38.2 | 23.6 |
| | 2-13-42 | 775,000 | 235,000 | 135,000 | 55,000 | 30.3 | 17.4 | 57.4 | 7.0 |
| | 2-20-42 | 1,510,000 | 355,000 | 105,000 | 90,000 | 23.5 | 6.9 | 29.5 | 5.9 |
| | 2-27-42 | 1,299,000 | 325,000 | 138,000 | 100,000 | 25.0 | 10.6 | 42.4 | 7.6 |
| Last sample through ice | 3-13-42 | 5,305,000 | 1,620,000 | 155,000 | 90,000 | 30.5 | 2.9 | 9.5 | 1.6 |
| Vernal overturn | 4-24-42 | 880,000 | 200,000 | 115,000 | 25,000 | 22.7 | 13.0 | 57.5 | 2.8 |
| | 5-16-42 | 1,920,000 | 370,000 | 220,000 | 90,000 | 19.2 | 11.4 | 59.4 | 4.6 |
| Heavy algal bloom | 5-29-42 | 1,405,000 | 330,000 | 240,000 | 65,000 | 23.4 | 17.0 | 72.7 | 4.6 |
| | 6- 6-42 | 2,150,000 | 375,000 | 300,000 | 50,000 | 12.7 | 13.9 | 80.0 | 2.3 |

counts of bacteria remained relatively uniform. The *Micromonospora* counts decreased during this time but the percentage of this group in its make-up of the chromogens remained high. From the time of the summer stagnation through September into the period of the autumnal overturn in October, the *Micromonospora* count continued to decrease. During this period counts were made of the *Actinomyces* of Group I. It is seen that their share of the total count is, with few exceptions, lower than their fellow genus the *Micromonospora.*

The lowest count of the *Micromonospora* was found in December as the first ice films formed over the lake. It is of interest to note that at this time and in the first sampling through the ice in January of 1942 there was a pulse in the total count of bacteria.

The ice crust of the lake made it possible, during January and on each Friday for the whole of February, to sample a confined area of the profundal depth. Each of the five holes chiseled through the ice was within the limits of a circle having a diameter of six meters. This permitted a sampling of the bottom with an accuracy greater than that afforded by sampling from a boat in an area not conducive to buoying the test spot.

Table IV shows that the *Micromonospora* count remained relatively uniform during this winter stagnation time. On the March 13, 1942 sampling, the last made through the ice, 5,300,000 bacteria per gram wet weight were detected. This was the largest total count of the entire season. Since, however, the *Micromonospora* had no part in this marked increase in total numbers, its percentage composition figure dropped to 2.9%—the lowest value of the year. In like manner, and for the same reason, the percentage of the *Micromonospora* of the chromogens was reduced to 9.5%—a low value when it is considered that on the September 3, 1941 testing the proportion of this group of organisms to the chromogens was 95.5%.

By the time the ice had disappeared and conditions made it possible to resume sampling, the lake had entered the period of vernal overturn. The summary of this period shows a rise in the count of the *Micromonospora* and a rise to a relatively high count of total organisms. The June 1942 reading, then completed a year's testing of a narrow area of Mendota bottom deposits. Table IV indicates that the May 1941 counts of the *Mi-*

TABLE V. A comparison of the numbers of bacteria found at three levels in core samples taken from an 18 meter depth area of Lake Mendota. The numbers are per gram wet weight.

| Level of core | Date | Total Counts | Chromogens | *Micromonospora* | *Actinomyces* |
|---|---|---|---|---|---|
| Sludge-top | 9-27-41 | 270,000 | 97,000 | 87,000 | 20,000 |
| | 1-17-42 | 1,056,000 | 258,000 | 96,000 | 78,000 |
| | 6-15-43 | 954,000 | 288,000 | 150,000 | 63,000 |
| | 7- 8-42 | 2,300,000 | 385,000 | 150,000 | 100,000 |
| Middle | 9-27-41 | 120,000 | 54,000 | 45,000 | 12,000 |
| | 1-17-42 | 380,000 | 92,000 | 58,000 | 14,000 |
| | 6-15-42 | 300,000 | 82,000 | 42,000 | 500 |
| | 7- 8-42 | 532,000 | 134,000 | 28,000 | 2,400 |
| Bottom | 9-27-41 | 25,300 | 160 | 160 | 160 |
| | 1-17-42 | 38,200 | 1,200 | 250 | 0 |
| | 6-15-42 | 25,200 | 750 | 0 | 0 |
| | 7- 8-42 | 41,700 | 10,000 | 0 | 0 |

*cromonospora* were the highest for the entire year. From this peak the counts dropped and with fluctuations reached the lowest counts during the winter stagnation period. After the vernal overturn the counts then appear to build up to another high value.

The results of a study made on four cores from the bottom deposits at the 18 meter depth are given in Table V. The three test-levels of the cores brought out the fact of the diminution of the total bacterial count as depth in the core was attained. The *Micromonospora* and *Actinomyces* were of very limited occurrence in the bottom level of the cores.

Figures 1, 2 and 3 show the progressive temperature changes of the open water of Lake Mendota from July 16, 1941 to July 8, 1942. The stages in the cycle of the year's changes of the lake are emphasized by the three figures. The first shows the lake during a summer stagnation; the second gives the marked differences before and after the autumnal overturn, and the third

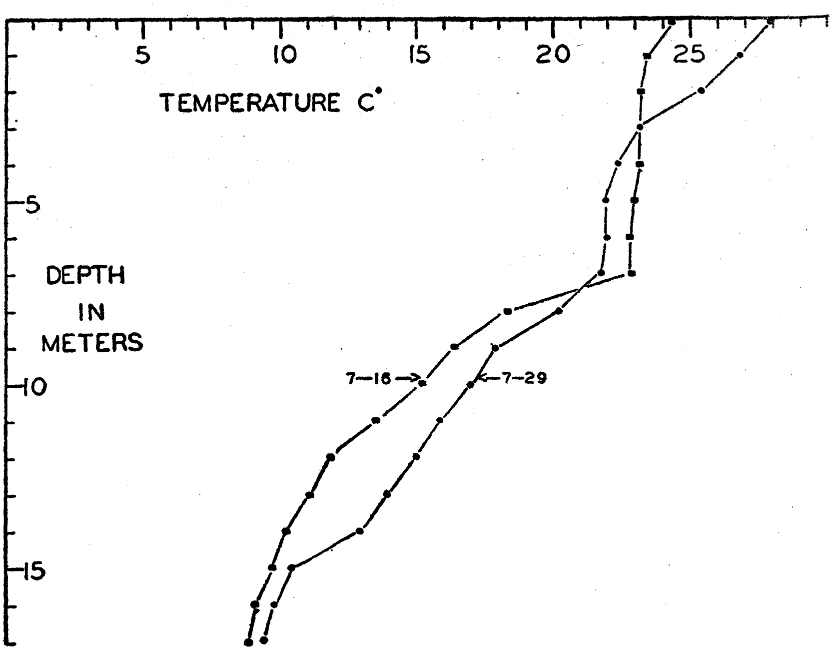


**Figure 1**
**Thermal stratification of Lake Mendota during July, 1941**

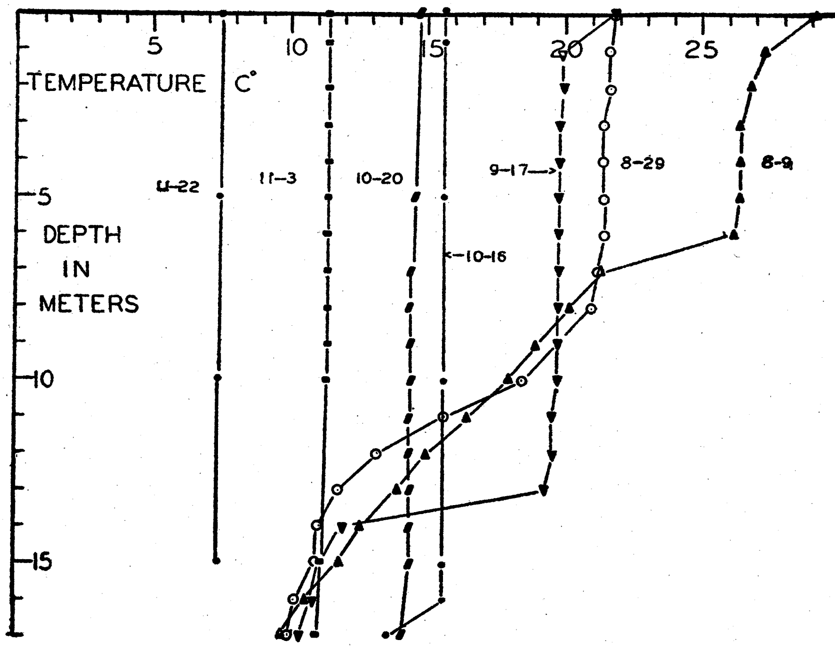


**Figure 2**

The thermal changes in Lake Mendota from summer stratification through the autumnal overturn in 1941.

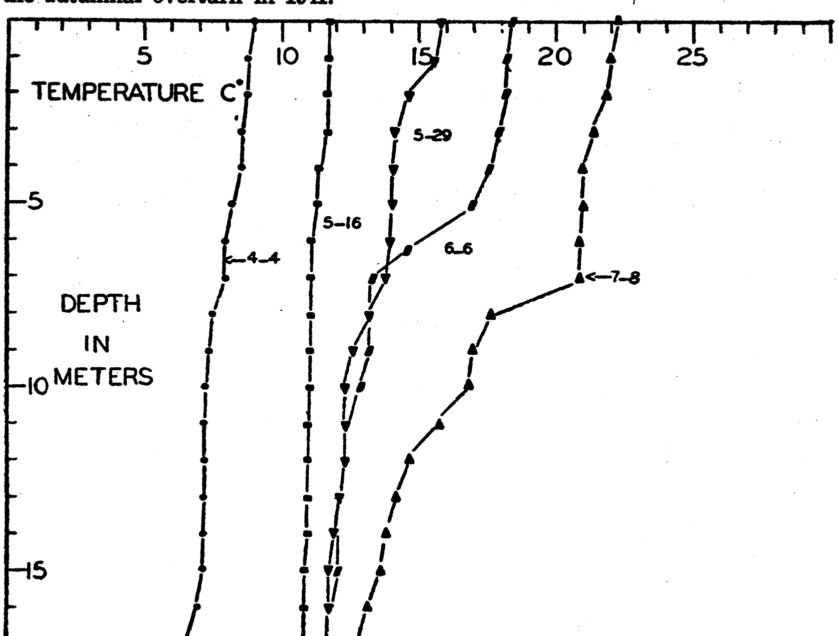


**Figure 3**

The progressive thermal changes in Lake Mendota from the time of the vernal overturn to early summer stratification in 1942.

**Table VI.** Vertical distribution of bacteria in the open water of Lake Mendota. The period of sampling shown comprises summer stagnation, autumnal and vernal overturn. Winter stagnation is recorded in Table VII. Total numbers of bacteria are first rows of figures; the second row of each column give *Micromonospora* colonies detected in replicable plates.

| | July | | August | | September | October | | November | | December | April | May | | June | July |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth in meters | 16 | 29 | 9 | 29 | 17 | 16 | 20 | 3 | 22 | 13 | 4 | 16 | 29 | 6 | 8 |
| 0 | 260 0-5 | 70 0-3 | 260 0-5 | 40 1-3 | 570 0-2 | 440 0-2 | 120 0-2 | 360 0-3 | 410 0-2 | 500 0-1 | 70 2-2 | 620 0-2 | 3850 0-2 | 910 0-3 | 630 0-2 |
| 1 | | 90 0-3 | | | | | | | | | | | 0-1 | | |
| 2 | | | 220 0-5 | | | | | 10 1-2 | 370 1-1 | 280 0-2 | 100 3-3 | 1070 0-2 | 2510 0-3 | 2290 0-2 | 990 0-3 |
| 3 | | | | | | | | | | | | | | | |
| 4 | 500 1-5 | 80 0-3 | | 60 0-3 | 240 0-2 | 760 0-4 | 120 0-2 | 180 0-3 | 390 0-2 | 760 2-3 | 20 3-3 | 920 0-2 | 530 0-3 | 2650 0-2 | 2040 0-3 |
| 5 | | | 860 0-5 | | | | | | | | | | | | |
| 6 | | 50 0-3 | 260 0-5 | | | | | | 330 0-2 | | 70 0-3 | 1170 0-2 | 800 0-3 | 2990 0-2 | 1120 0-1 |
| 7 | | | | | | | | | | | | | | | |
| 8 | 820 1-5 | 100 0-3 | | 420 0-3 | 1700 0-3 | 490 0-5 | 140 1-1 | 560 1-3 | 450 2-2 | 630 1-2 | 230 1-2 | 1410 1-3 | 540 1-3 | 1420 1-3 | 800 1-3 |
| 9 | | | | 680 0-3 | | | | | | | | | | | |
| 10 | | | | 220 0-3 | | | | 460 0-3 | 310 1-3 | 520 1-0 | 150 4-3 | 970 0-1 | 350 0-3 | 2230 0-2 | 1090 0-3 |
| 11 | | | | 160 0-3 | | | | | | | | | | | |
| 12 | 160 2-4 | | 1940 0-5 | 130 0-3 | | 360 0-5 | 150 0-2 | 350 0-2 | 490 3-3 | 650 0-1 | 150 2-3 | 1220 1-3 | 120 2-3 | 1500 0-2 | 690 0-1 |
| 13 | | | | | 2700 0-3 | | | | | | | | | | |
| 14 | | 60 1-3 | | | 280 1-3 | | | 280 1-3 | 450 0-2 | 320 3-3 | 120 3-3 | 1420 0-3 | 130 0-2 | 830 1-2 | 1310 0-2 |
| 15 | | | | | 150 1-2 | | | | | | | | | | |
| 16 | 60 1-4 | | | 90 1-3 | | 860 0-5 | 170 0-2 | 25 0-2 | 440 0-1 | 390 0-2 | 220 5-2 | 950 0-2 | 190 1-2 | 1350 0-2 | 1850 0-2 |
| 17 | | 40 0-3 | 680 0-5 | 40 0-3 | 150 1-3 | | 180 1-3 | 20 1-2 | 260 4-3 | | 180 4-2 | 1780 0-2 | 200 1-3 | 1650 0-2 | |
| Bottom Water | | | | | | | 7000 4-2 | 720 7-3 | 390 4-2 | 720 0-2 | 390 4-2 | 2340 0-3 | 270 1-3 | 2180 0-2 | 2080 1-1 |
| *Micro.* Totals | 5-23 | 1-21 | 0-30 | 2-25 | 3-18 | 0-21 | 2-12 | 4-23 | 11-21 | 7-14 | 27-26 | 2-22 | 5-28 | 2-22 | 1-20 |

figure presents the progressive changes leading to a resumption of stratification after the vernal overturn.

The results of the investigation of the vertical distribution of bacteria in the open water of Lake Mendota are given in Tables VI and VII. The samples were collected from the waters overlying the 18 meter station.

A study of Table VI shows both the counts secured by centrifuging the water sample prior to plating and the counts secured by the regular plating procedure. All water samples tested during the period of August through February were centrifuged at approximately 1800 R.P.M. for 15 minutes. No marked increase in bacterial counts can be attributed to this procedure.

Those water samples secured by allowing the Wilson sampler to enter the edge of the bottom sludge before taking the sample were, with few exceptions, higher in bacterial content than the free water above. These counts cannot be evaluated too rigidly as water counts since the sampler necessarily caused a disturbance by its descent into the sludge layer.

The *Micromonospora* count is recorded as the number of colonies developing replicate plates. This mode of recording has been selected rather than the conventional report of numbers of colonies per cc. The percentage of these organisms developing on the total number of plates poured at any particular date of sampling is given in Tables VI and VII.

It will be noted that in comparatively treated samples of water (the centrifuged ones) the percentage of *Micromonospora* increased in the late November sampling, remained high during December and January and then dropped in February. Another increase in these organisms in the water occurred in the April testing at the time of the vernal overturn. During June, July and August—a period corresponding to the summer stagnation —the percentage of *Micromonospora* colonies developing on the plates of these water samples again was low.

If the summary of the *Micromonospora* appearing on the plates from any water level is considered, it will be noted that there is no gradation of frequency of these organisms from any one depth to another nor is there any marked accumulation of

TABLE VII. Vertical distribution of bacteria in water under ice layer of Lake Mendota. The samplings comprise the winter stagnation period. Total numbers of bacteria are first rows of figures; the second row of each column give *Micromonospora* colonies detected in replicate plates.

| Depth in meters | January | | February | | | |
|---|---|---|---|---|---|---|
| | 13 | 17 | 6 | 13 | 20 | 27 |
| 0 | 70 0-3 | 190 1-3 | 47 0-4 | 60 1-4 | 330 0-3 | 50 0-0 |
| 1 | | | | | 150 1-3 | |
| 2 | 70 1-3 | 180 1-3 | 12 0-4 | 60 0-3 | 170 0-3 | 35 0-2 |
| 4 | 90 2-3 | 110 2-3 | 12 0-4 | 80 0-4 | 140 0-3 | 40 0-3 |
| 6 | 180 0-2 | 110 1-3 | 17 1-4 | 120 0-4 | 270 0-3 | 70 0-3 |
| 8 | 240 0-3 | 610 1-2 | 160 0-4 | 15 0-4 | 260 0-3 | 50 0-3 |
| 10 | 200 1-3 | 110 1-3 | 220 0-4 | 190 0-4 | 250 0-3 | 110 0-3 |
| 12 | 50 0-2 | 90 4-3 | 220 1-4 | 340 0-4 | 400 0-3 | 200 0-3 |
| 14 | 220 3-3 | 40 0-3 | 220 0-3 | 230 0-4 | 370 1-3 | 130 0-3 |
| 16 | 410 5-3 | 110 2-2 | 220 2-4 | 180 2-4 | 130 1-3 | 130 0-3 |
| 17 | 200 2-3 | 240 5-3 | 720 0-2 | 930 1-4 | 390 2-4 | 170 0-3 |
| Bottom Water | 1250 1-2 | 330 2-3 | 920 0-3 | 1180 0-2 | | 320 1-3 |
| *Micro.* Totals | 14-28 | 18-28 | 4-37 | 4-39 | 8-54 | 0-26 |

them at any level corresponding to the epilimnion or thermocline. It was only in the bottom levels of the hypolimnion that the percentage of these organisms showing on the plates had an appreciable value over that of the overlying waters.

Table VII contains the results of six samplings of the waters under an ice crust. The last four of the series were made seven days apart, and one of these testings comprises a sampling of the water at each meter of depth. More uniformity is shown in the sampling (February 20, 1942) than in any of the others. A small Gram-negative yellow chromogen was the predominating organism developing on the plates. The table shows also that waters next to the ice crust have a lower bacterial content than the lower water in four of the six samplings made.

The *Micromonospora* count in the water under winter stagnation conditions indicates that more of these organisms are in the water at the beginning of the period than toward the end of this part of the lake's cycle. It is also shown in Table VII that the level of the water has no greater influence on *Micromonospora* counts during the winter stagnation than Table VI showed to be true in the case of open water at different levels.

## *MICROMONOSPORA* IN RELATION TO LAKES AND LAKE POPULATIONS

Study of the soil actinomycetes has brought out the fact that the group grows in a wide variety of environments. These organisms characteristically occur in habitats where there is a ready access to air, where there is much surface exposed and which is relatively dry.

The actinomycetes have been considered instrumental in decomposing the more resistant materials found in the soil. The work of Jensen (1930, 1932) indicated that within the soil actinomycetes group the *Micromonospora* had some of the functions exhibited by the members of the better known genus, *Actinomyces*. Thus, a soil enriched with crude lignin from oat straw and, in another case, with cellulose, gave marked increase in the counts of *Micromonospora*.

Few later reports have been seen dealing with these organisms either in regard to their numbers or their activities in the soil. Kriss (1939) has reported a new species found in Russian soil. Waksman, Umbreit and Cordon (1938) found *Micromonospora* in composts having a temperature range of 50 to 60 degrees C. These organisms were found in the heated plant masses at times varying from one to 15 days. No report has been seen giving numbers found in American soils.

To determine the presence or absence of *Micromonospora* in some Wisconsin soils, plots of both cultivated and uncultivated lands were investigated by the plating out of representative samples upon the three media used in the studies on the flora of the bottom deposits. Also, many plates of different soils have been studied after student-experimentation pursuant to their laboratory work in varied courses in the Department. Too, numerous samples of soils have been investigated which lie adjacent to some of the lakes, Mendota, Crystal, Trout, Little John, Nebish, Muskellunge. Counts of *Actinomyces* varying from approximately 30 thousand to 10 million per gram of soil were found depending upon the soil type. Few *Micromonospora* colonies were demonstrated on those dilution plates which had such colony separation that identification of the organism was possible.

Near the University Bay section of Lake Mendota an area of farm land has been reclaimed from the old lake bed. Constant pumping is required to empty the sumps into which the tile system empties its water. Samples of the water in the collecting sumps and from the ditch which leads to the lake failed to disclose the organisms except in one instance where a single colony was found.

The actual shores of the lakes above the limit of wave wash have been tested. Although *Actinomyces* have been found, this was not true of the *Micromonospora.* One testing period was immediately after a heavy rain. Not only did the sand and soil of the shore fail to disclose the *Micromonospora,* but tests made on the murky water adjacent to the shore did not show the organisms.

It is, therefore, clear from these studies that, although the particular cultivated soils tested and the soils of regions about some of the lakes studied did have *Actinomyes,* none of them had *Micromonospora* in such quantities that the plating of the soils demonstrated them in sufficient numbers that they would be considered of any significance.

Starkey (1939) in studies on soil flora in regard to the numbers of microorganisms found in close proximity to plants, has stated that the plant itself occupies a unique place in soil studies. Of all the factors determining the abundance and nature of the soil population, it is the plant itself which is preeminent. The nature and abundance of materials derived from plants regulate the development of the organisms more than any other single factor. But, although the plating technique showed bacteria about plant roots in greater number than elsewhere, it is interesting to note that he found very little increase in abundance of the *actinomycetes.*

That the bacterial flora of the water of the shallow bay areas far exceeds that of the open water at the same levels (0-2 meters having been studied) has been shown by Stark and McCoy (1938). They found that the organic content of such areas, influenced by weeds and algal growth, had a greater effect upon the numbers of bacteria than did the factors of temperature, oxygen content and shore contamination.

Umbreit and McCoy (1941) suggested in their paper that attachment to water plants, from which they might receive oxygen, might be a possible locale for the growth of *Micromono-*

*spora.* It is also conceivable that the debris of such plants would, upon their remains leaving the littoral zones during the fall overturn, aid in distributing the organism over the lake. However, a study of *Sagittaria, Lemna, Patamogeton, Vallisneria* and lake bulrush at different positions in the bay and shore areas did not disclose members of the genus *Micromonospora.*

Lake Mendota had, during some of the summer months tested, large masses of algae floating in the surface waters. These algal mats were examined and were found to be lacking in *Micromonospora.* The results of the late May, the June and the early July water testing shown in Table VI can be used to demonstrate again the fact that the *Micromonospora* are not concerned with algal matter found in the water. This table shows that during the bloom and subsequent sinking of the vast numbers of this plankton material the bacterial count rose, but the *Micromonospora* and *Actinomyces* counts did not.

This finding of a bacterial pulse correlated with the bloom of algal plankton material, while not connected directly with the *Micromonospora,* is of interest in showing that in waters, as in soil, there is a microbial response to the addition of readily fermentable material.

The open waters of the Wisconsin lakes have been reported by the workers cited before as being remarkably low in bacterial numbers even though the organic matter present in the water is of such quantity that higher populations could be supported (Stark 1939).

The bacterial counts of the water reported in this paper show that Lake Mendota surface waters are usually low in number. However the results of the water testing of the late May, the June and the early July period of 1942 indicate that when a readily decomposable matter, such as the material of an algal bloom, is available, there is marked response on the part of the water bacteria.

On the May 16 examination, and before the bloom was noticeable, 620 bacteria per cc were found at the zero station and 1070 per cc at the two meter depth. Because the bloom was very noticeable on May 29 the one meter depth was sampled then also; hence Table VI shows that, in addition to the increase demonstrated by the counts of 950 and 2510 bacteria per cc secured at the zero station and two meter depth respectively, a count of

3580 bacteria per cc was detected at the one meter station. This was the largest number demonstrated in the upper waters of the lake.

Thus, in a narrow zone of water bounded by the surface above and the two meter depth below made rich by the food materials afforded by the algal matter, there appeared a marked increase in the numbers of bacteria in comparison with the numbers shown in the same zone in the two previous testing periods prior to the pulse of the algae.

The June 6 testings indicate, at once, both the fact that the settling of the algal matter causes a rise in the bacterial counts in the waters under the two meter zone, and, upon the passage of the decomposing matter away from this zone, that the surface station returned to the usual low bacterial count.

Whitney (1937), making use of a transparency meter, has demonstrated microstratification in the hypolimnion of temperate lakes which stratify into an epilimnion, a thermocline and a hypolimnion during the summer. His data showed that in areas of maximum and minimum transparency there were great differences in bacterial counts. In one instance at a 16.0 meter transparency minimum there was a 200 to 1 relative count over an area but 0.4 meter deeper. It was interesting to note that in the high count area there was a large number of organisms appearing as pin-point colonies on the particular plates poured from that water.

It might well be that this finding of Whitney is a more common occurrence than might be considered at first glance. Large masses of bacteria associated with the debris from plankton, settling down through the water, may be localized in a given area depending upon the physical condition of the lake at that time, and, as a result, cause a pulse of bacteria that might appear in the form of a crest of a wave as it progresses downward. Needless to say a testing of the bottom deposits after the arrival of such a bacterial pulse would be markedly influenced by such an addition.

In the examination of the open water of Mendota the possibility was considered that the stratification of the water during the summer stagnation period might cause a concentration of *Micromonospora* in any of the three levels of the lake. Whitney suggested that it could be that the lake acted as a great filter.

Since the greatest changes in transparency occurred at regions of relatively large temperature change, this might be indicative of a sorting in which particles of different sizes, shapes and densities have their rate of settling affected and thus accumulate at levels which are determined by the factors of temperature and other physical conditions.

Figures 1, 2 and 3 show the thermal condition of the lake at the test periods. Samplings were made during summer stagnation so that the three layers of water would be investigated for any localization of the *Micromonospora* at any of the levels. In the other periods of testing, portions of the waters were taken so that a distribution from top to bottom could be secured. It was only during the periods following the two overturns, when the waters had been stirred to the profundal depths, that there was an apparent increase in *Micromonospora* counts of the water. This increase, since investigations have proved that additions from the soil are minimal, was due to the resuspension of *Micromonospora* which had been at the sludge-water interface.

Tables II and III indicate clearly the marked correlation between the amount and kind of organic matter in the bottom deposits with the numbers of *Micromonospora* found in such lake deposits.

Henrici (1940) found that the occurrence of aquatic plants determines the shoreward distribution of bacteria of the bottom deposits. Where the plants are abundant, bacteria are numerous. But Henrici and McCoy (1938) also found that if the shore is sandy and, because of wave action, is free of rooted plants, then a marked decrease in the bottom bacteria is noted as the shore is approached from the profundal depths.

The numbers shown in Table II for Ripley and Waubesa bring out the correspondence between depth and *Micromonospora* count. However, depth, *per se*, is not the criterion for the determination of the count of these organisms, but rather an indication that as this feature increases in magnitude the type of bottom deposit usually changes from sand and coarse materials to the finer particles characterizing the profundal depths. At the six meter depth in Ripley the bottom sludge was not as fine in size, was not as black and did not have the characteristic appearance of the black fine sludge of the 12 meter depth. The counts of *Micromonospora* at the two stations were 30,000 and 65,000 respectively per gram of wet weight.

In Waubesa, a lake lacking the depth of Ripley, the deposits graded from a coarse, plant-debris-laden, chalky-grey deposit to one of a finer nature; but even at the seven meter depth the sludge lacked the blackness and fineness detected in Ripley and Mendota. Here, too, the *Micromonospora* count increased with depth.

The comparison of Monona and Wingra in Table II indicates again that the nature of the bottom deposits and not necessarily depth determines the frequency of these organisms. The Monona sample was lacking in organic matter and had a high proportion of shells; it was taken at a depth of four meters and had but a 400 organisms per gram count of *Micromonospora*. Wingra, on the other hand, at a depth of but two meters gave 68,000 *Micromonospora* per gram of wet weight. In this sample the deposit was rich in organic matter.

Table III, summarizing one study of Lake Mendota, brings out in greater detail this feature which already had been indicated by other lakes listed in Table II. Mendota was studied in four areas: the bay and shore area, the 6.5 to 10.0 meter area off-shore, the 13.0 to 15.0 meter area approaching the depression opposite the Observatory and, finally, the 18 meter profundal area.

In the bay area and in the 6.5 to 10.0 meter zone the *Micromonospora* count was low; the deposits in these areas were sand, shells, and coarse plant detritus. The *Micromonospora* count increased in the 13.5 to 15 meter zone. Many of the samples secured from this area approached those taken from the 18 meter depth in appearance and, indeed, the *Micromonospora* counts on some of them varied but little from the results secured at the deepest area.

An examination of Tables III and IV shows other features concerning the bacterial numbers of the four areas. Very clearly the bay area is richer in total counts and in chromogens than the off-shore area which also bears rooted vegetation. This difference may be attributable to the protection from wave action which, in the case of the off-shore area, is much more pronounced and would thus markedly influence the quantity and quality (the finer particles are easier carried away by water currents) of the organic material present in the area. Except for the testing of May 16, 1942, which showed upon plating a high number of yellow chromogens, the count in all respects of these two littoral sections were lower than those of the transition zone as demonstrated by the 13.0 to 15.0 meter area. There seems to be no marked difference in the numbers of bacteria in any area when the season of year is taken as the basis of comparison.

Table IV shows the only instance where there might be a correlation between season-cycle and number of bacteria. This table summarizes the attempt to find if *Micromonospora* in the bottom deposits of a definite area do go through a seasonal variation.

Williams and McCoy (1935) noted only a minor difference between the counts of bottom deposits in winter and summer in their study of some deposits of Lake Mendota. In his excellent treatment of the distribution of bacteria in lakes, Henrici (1940) states that not many data have accumulated on the subject of seasonal variations of lake bacteria. Most of the work that has been reported deals only with the free water and, as Henrici states, winter observations are lacking.

Domogalla, Fred and Peterson (1926) have indicated that there is a seasonal variation in bacterial numbers by their work on the nitrogen cycle as affected by bacterial action. Fred, Wilson and Davenport (1924), early workers in the field of lake bacterial studies, had results that varied from year to year in their three-year study. Their maximum of the water bacterial counts varied in the three years from a summer, an autumn and a spring maximum. Graham and Young (1934) noted a summer minimum in Flathead Lake.

Umbreit and McCoy (1941) felt that *Micromonospora* might be more concerned, in their life in bottom deposits, with the quality of the organic matter present rather than with the quantity of this substrate. The higher counts of *Micromonospora* found in the period after the vernal overturn and before stratification had begun is suggestive that such a situation is indeed possible.

After the spring and summer growth of plankton and water plants has taken place and the high winds and consequent water movements of the autumnal overturn have removed their remains together with soil-introduced organic matter away from the littoral zones to the areas where selective settling acts upon them, it is seen that the more rapidly utilizable materials serve as food for those organisms which respond rapidly to the influx of such foodstuff. The growth of *Micromonospora* is so slow that the organisms cannot compete with those faster growing bacteria found in the deposits in much large numbers. During the winter stagnation period when the oxygen content of the muds is minimal, these plant remains undergo further breakdown so that by spring a resistant organic matter is present. This material then could be the subtrate for *Micromonospora* as they are known to grow on very resistant organic materials (Erikson 1940).

To test just the detritus of plant origin, of a size that would be caught by a number 20 screen, such materials were obtained from the 18 meter station and from the 13.0 to 15.0 areas. The substances were ground in a mortar with sterile sand and then used as the source material for the study of *Micromonospora* counts. Samples from the 13.0 to 15.0 meter area gave a count of 40,000 per gram while the materials secured from the 18 meter station were 190,000 per gram of wet weight.

Tests underway in the laboratory at present indicate that such materials as leaves, straws and cellulose when added to the bottom muds cause an increase in *Micromonospora* counts.

The number of chromogens found in lake waters and deposits has frequently been mentioned by the investigators of lake flora. Jansky (1936) characterized some bacteria from the northern Wisconsin lakes with emphasis on the chromogens. She felt that the grouping of these water organisms on the basis of color formation seemed to indicate that chromogenesis might be of value at least in the grouping, if not in identifying, the lake bacteria.

It was possible to study 31 chromogens of the cultures resulting from her work. Of the 31, five were identified as *Micromonospora*. Three, of these five, had been described by this worker as "reddish brown actinomycetes."

An objection raised to the sampling of bottom deposits by the core procedure revolves about the subject of compaction of the sample. This is a valid objection, and it minimizes the significance of counts at exact depths. It was found in this portion of the study that, although the sampler was driven into the mud to such a depth that even the lead weight became fouled, still upon subsequent removal of the core from the sampler in the laboratory, there would be found a length of mud approximately one-half the length of the tube. For this reason the areas of the cores sampled were arbitrarily but three: the top, the middle and the bottom of the core, no attempt being made to specify their actual position in centimeters in depth in the core.

It is well to mention the middle sample. Every core observed had a sudden marked color change from the typical black of the upper sludge to the marl color of the typical bottom portion of the core. This transition took place in the cores at approximately 15 cm from the top. The middle samples for bacterial analyses were taken so that half of the 25 grams of the test material came from each side of this color plane.

Henrici and McCoy (1938), Carpenter (1939), Williams and McCoy (1935) have investigated bottom deposits of some Wisconsin lakes. Henrici and McCoy found that plate counts showed a marked decrease with depth in the mud. They felt that there was an indication "that bacterial activity at the bottom of lakes is carried on almost exclusively at the mud-water level, the bacteria dying below." Williams and McCoy found a mean average count of 5,200,000 bacteria per gram dry basis for the top samples of the Mendota cores and a mean count of 90,000 for the bottom samples. Their work indicated that only minor differences in numbers and kinds were noted in the comparison of winter with summer samples. Carpenter's work on Crystal Lake showed the same great difference between the total numbers found in the surface mud and that of the lower deposits. The average count of 2120 aerobic or facultative per gram of dry weight for the surface mud and a count of 114 for the bottom mud, when compared with the corresponding counts for Lake Mendota, bring out the marked differences in the bacterial counts of the bottom deposits of the two lakes.

Table V indicates that the *Micromonospora* and the *Actinomyces* decrease sharply in numbers as the depth below the mud-water interface increases. In the marl-like bottom portions of the cores their portion of the total count is negligible. In like manner the chromogens of any individual sample show this lessening in numbers as the black sludge area is left and the

$CaCO_3$ rich portion approached. The percentage of the *Micromonospora* based on total chromogen counts, as the depth in the core is increased has no regularity. It is of interest, however, to find that *Micromonospora* do make up a major proportion of those chromogens which have been noted by the former investigators of the cores from this lake.

The 9-27-42 core had 89.6% and 83.3% as values representing the *Micromonospora* portion of the chromogens present in the top and middle samples of the core. In the 1-17-42 samples these values were 37.2% and 63.0%; in the 6-15-42 core, 52.0% and 51.2%; while the last core, 7-8-42, dropped in value to 38.9% and 20.8%.

*Micromonospora* members are resistant to the deleterious effect of drying and their spores remain viable for years. Cores of Lake Mendota and Wingra muds, which had been taken in 1932 and which had been dried in a 37°C. incubator and stored under aerobic conditions in the laboratory for the intervening years, gave upon testing in 1942 high counts of *Micromonospora.* One sample of dried surface mud gave a count of 170,000 per gram and a sample of the bottom of a core had 6,000 per gram.

## SUMMARY

This report is based on a bacteriological survey of the bottom deposits of 13 Wisconsin lakes. Varying numbers of *Micromonospora*, a member genus of the family *Actinomycetaceae*, have been found in all of the lakes. The northeastern lakes studied have a smaller number of *Micromonospora* than do the lakes of the southern part of the state.

Although *Actinomyces* are numerous in soil areas adjacent to the lakes, few *Micromonospora* have been found.

No association was detected between *Micromonospora* and growing water plants or with phytoplankton. An occurrence of a pulse in the bacterial count of open water due to an algal bloom has been discussed.

Bottom deposits of littoral zones and areas subject to wave action were found to have smaller numbers of these organisms than the profundal zones rich in organic matter. There were evidences that in profundal depths an increase in numbers of

*Micromonospora* took place following the vernal overturn. An explanation for this seasonal peak has been offered. Vertical distribution of *Micromonospora* in cores shows a rapid decrease in numbers from the surface of the sludge downward.

Lake waters had negligible numbers of *Micromonospora*. An increase in the count of these organisms occurred only at the two overturns when bottom muds had been agitated and the organisms had been distributed throughout the overlying waters.

The percentage distribution of the *Micromonospora* within the chromogenic group of bacteria is high in the bottom deposits of the profundal areas. There was a range from 9.5% to 95.5% with an average of 61.6%. The percentage that the *Micromonospora* make up of the numbers of bacteria in the bottom deposits varied from 2.9% to 48.5% with an average of 13.4%.

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# PHYSICAL FACTORS INFLUENCING THE ACCURACY OF THE DROPPING MERCURY ELECTRODE IN MEASUREMENTS OF PHOTOCHEMICAL REACTION RATES

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*From the Limnological Laboratory of the Wisconsin Geological and Natural History Survey, Notes and reports No. 115.*

## INTRODUCTION

Dropping mercury electrodes have recently been used for measuring changes in dissolved oxygen produced by photosynthesis and respiration (1, 3, 5, 6). This method of oxygen determination should also prove valuable for non-biological photochemical studies in aqueous solutions.

With the analytical procedure used in most photochemical studies, it is possible to measure only the total effect produced in a reaction vessel by a given amount of absorbed light. In this respect, the dropping mercury electrode is almost unique, since it measures a concentration effect which, in the absence of disturbing factors, is confined to the immediate vicinity of the dropping mercury capillary tip, regardless of the size of the reaction vessel. Because of this characteristic, the electrode can be used to measure dissolved oxygen changes in very small volumes of solution, a distinct advantage where limited amounts of material (or of light) are available. Another advantage of this method is its simplicity of operation, particularly when relative, rather than absolute, rate measurements are desired.

The measurement of local concentration changes, in a vessel containing a wide range of light intensities, results in complications not ordinarily encountered in photochemical studies. The purpose of this paper is to evaluate quantitatively some of these complications in relation to the rate and extent of light absorption, and to point out the conditions under which the dropping mercury electrode can be used with maximum accuracy. Emphasis is placed on the difficulties encountered in measurements with biological material, where the choice of experimental conditions is usually subject to severe limitations. Although the factors involved are discussed only in relation to measurements with the dropping mercury electrode, the discussion is not specific for this method; it would apply to any method in which a photochemical reaction in liquid phase is studied by measuring local concentration changes. Accordingly, no mention will be made of problems more specifically related to the use of the dropping mercury electrode. These are discussed elsewhere (4, 5).

Effective stirring of a liquid reaction mixture during illumination tends to equalize the rate of change in all parts of the reaction vessel. In one sense then, a method measuring a local concentration change becomes a method measuring total reaction. Stirring serves to eliminate many of the complications discussed below, but it also eliminates some of the advantages of the dropping mercury electrode method. Moreover, effective stirring cannot always be provided. In nearly all quantitative photochemical investigations, a thin flat reaction vessel is desirable or essential; in investigations involving a study of changes in concentration of a gas dissolved in a liquid, it is highly desirable that the vessel be completely filled with liquid. Because of these two requirements, satisfactory stirring is difficult. Moreover, one of the principal advantages of the dropping mercury electrode lies in the possibility of using it in very small reaction vessels, where stirring is still more difficult.

Except where specifically stated to the contrary, the equations derived in this paper are strictly applicable only in cases where monochromatic light is used and where reaction rates are approximately proportional to the light intensity. However, the modifications necessary for treatment of other cases will usually be evident.

## THE INFLUENCE OF LIGHT ABSORPTION ON THE ACCURACY OF QUANTUM YIELD MEASUREMENTS

For a parallel beam of monochromatic light incident on the front window of a dropping mercury electrode vessel, the light intensity at any distance $x$ cm. from the front window is, according to the Beer-Lambert law,

$$I_x = I_0 e^{-kx} \tag{1}$$

where $I_0$ is the incident intensity inside the window and $k$ is proportional to the concentration of light-absorbing material. Equation 1 is not strictly accurate where the absorbing material is not in true solution but rather in suspension. A suspension will cause scattering as well as absorption of the incident light. A larger and larger fraction of the unabsorbed radiation will be scattered as it progresses through a suspension, thus increasing the effective path length and causing an apparent increase in the value of $k$ as $x$ increases. However, measurements have shown that for suspensions of the alga *Chlorella*, this effect is too small to have any important influence on the factors to be considered here.

*Reaction rates*

The dropping mercury electrode measures changes in oxygen concentration only in the immediate vicinity of the capillary tip. The tip is usually placed midway between the two cell windows (at $x = s/2$ if the distance between the windows is $s$). Then for measurements where the rate of oxygen change is directly proportional to the light intensity, and in the absence of mixing due to diffusion or convection, the measured rate at the capillary tip may be defined by[1]

$$R_{s/2} = \frac{(\Delta O_2)_{s/2}}{dx} = \gamma k I_{s/2} = \gamma k I_0 e^{-ks/2} \qquad (2)$$

where $(\Delta O_2)_{s/2}$ is the number of oxygen molecules produced or consumed per second at $x = s/2$ in a volume element of one square centimeter cross-section and thickness $dx$, $\gamma$ is the quantum yield (molecules of oxygen produced or consumed per quantum absorbed), $k$ is the rate of light absorption (as in equation 1), and $I_{s/2}$ is the light intensity at the tip, in quanta/cm.$^2$/sec.

Using equation 2, the quantum yield, $\gamma$, may be evaluated (assuming $s$ to be known) from measurements of $R_{s/2}$, $I_0$ and $I_s$.

In actual practice, as the reaction proceeds, an oxygen concentration gradient will be set up because of the varying rate of production (or consumption) at the various light intensities throughout the reaction vessel. At the same time, diffusion and

[1] In equation 2 and in subsequent equations, it is assumed that the concentration of light-absorbing materials does not change appreciably during a period of measurement.

convection will tend to equalize the oxygen concentrations throughout the vessel. The maximum or limiting effect of diffusion would be to equalize the rate of oxygen change in all parts of the reaction cell. If this condition were to prevail, the measured rate at the capillary tip could no longer be expressed by equation 2. Instead, the rate should be defined by

$$R_{s/2} = \frac{\text{(quantum yield)} \times \text{(total absorbed quanta/cm.}^3\text{/sec.)}}{\text{thickness of cell in centimeters}}$$

$$= \gamma' \ (I_0 - I_s)/s = \gamma' I_0 (1 - e^{-ks})/s \qquad (3)$$

*Uncertainty due to diffusion and convection*

In an actual experiment, the true quantum yield should be somewhere between the two values calculated for no diffusion and maximum diffusion. An experimental measurement will thus be subject to an uncertainty which may be represented by the equation

$$\text{Uncertainty} = (\gamma - \gamma')/\gamma = 1 - \frac{kse^{-ks/2}}{e^{ks} - 1} \qquad (4)$$

The effect of diffusion might be calculated and corrected for, but little would be gained by this procedure, since the variable and almost unpredictable convection factor would remain.

The order of magnitude of the rate of mixing by diffusion and convection can be estimated from Fig. 1, which shows the results of a preliminary experiment by Day and Daniels (cf. reference 2) on the photochemical oxidation of methyl-ethyl ketone. In this experiment, the ketone concentration was high, with over 90% of the incident radiation absorbed. A period of about 10 minutes after irradiation was required for the oxygen concentration to become approximately constant. The exact rate of mixing would vary considerably with different experimental conditions, but Fig. 1 indicates that, in general, neither equation 2 nor equation 3 can be used satisfactorily when the fraction of absorbed light is very large. In cases where it is known that no thermal reaction involving oxygen can occur, equation 3 or an equivalent formula may often be used for quantum yield calculations, if sufficient time is allowed after irradiation for complete mixing of the dissolved oxygen.

It can be shown that the ratio $\gamma'/\gamma$ approaches a value of one as the product $ks$ approaches zero. Consequently, the un-

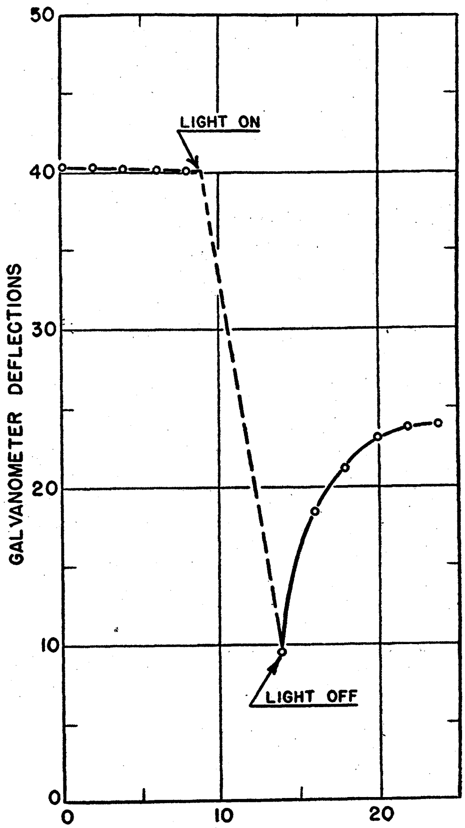


**FIGURE 1.** Changes in observed oxygen concentration as a result of photo-oxidation of methyl-ethyl ketone (data of Day and Daniels). The increase in oxygen concentration after irradiation is caused by diffusion and convection.

certainty defined by equation 4 may be reduced either by using a more dilute solution or suspension or by using a thinner reaction vessel. Table I gives the calculated uncertainty for several values of *ks*.

TABLE I

| *ks* | Light transmission | Uncertainty |
|---|---|---|
| 0.50 | 60.7% | 0.010 |
| 0.69 | 50.0 | 0.020 |
| 1.00 | 36.8 | 0.039 |
| 1.50 | 22.3 | 0.088 |
| 2.00 | 13.5 | 0.148 |
| 2.50 | 8.2 | 0.220 |
| 3.00 | 5.0 | 0.296 |
| 4.00 | 1.8 | 0.449 |

A value midway between $\gamma$ and $\gamma'$ may be chosen advantageously as the quantum yield to be calculated from rates measured by the dropping mercury electrode, since the maximum error due to the diffusion and convection factors is then only one-half of the calculated uncertainty range. The equation for the calculated quantum yield is then

$$\gamma_c = (\gamma + \gamma')/2 = \frac{R_{s/2}}{2I_o}\left(\frac{e^{ks/2}}{k} + \frac{s}{1-e^{-ks}}\right) \qquad (5)$$

*Uncertainty for non-monochromatic light*

Equations 1 to 5 are strictly valid only for monochromatic light or for cases where the rate of absorption, $k$, is constant over the range of wavelengths used. In actual experiments, the incident light is seldom truly monochromatic, but with a narrow band of wavelengths such as is frequently used, variations in $k$ may often be small enough so that the equations are still approximately correct.

Where the experimental conditions do not fulfill the above requirements, equation 1 must be replaced by the more general form

$$I_x = (I\lambda_1)_o e^{-k_1 x} + (I\lambda_2)_o e^{-k_2 x} + \ldots. + (I\lambda_n)_o e^{-k_n x} \quad (1')$$

where $(I\lambda_1)_o$, $(I\lambda_2)_o$ etc. are the incident intensities (in quanta/cm.$^2$/sec.) for the various component wavelengths, and $k_1$, $k_2$, etc. are the corresponding absorption coefficients.

Equation 4 then becomes

Uncertainty =

$$1 - \frac{s\left[k_1(I\lambda_1)_o e^{-k_1 s/2} + k_2(I\lambda_2)_o e^{-k_2 s/2} + \ldots. k_n(I\lambda_n)_o e^{-k_n s/2}\right]}{(I\lambda_1)_o(1-e^{-k_1 s}) + (I\lambda_2)_o(1-e^{-k_2 s} + \ldots. + (I\lambda_n)_o(1-e^{-k_n s}} \quad (4')$$

The uncertainty given by equation 4′ for non-monochromatic light and varying $k$ will always be greater than the uncertainty for monochromatic light with the same value for $I_s/I_o$. Qualitatively, this is evident from the fact that wavelengths for which the absorbing material has a large $k$ will form a constantly diminishing fraction of the total light as it passes through the reaction vessel. The total rate of absorption will be correspondingly diminished. As a result, when non-monochromatic light is used, the intensity at the center of the vessel will correspond less closely to the average intensity than it would in the case of monochromatic light.

The magnitude of this effect under somewhat extreme conditions can be seen from calculations based on the distribution of wavelengths and absorption coefficients shown in Fig. 2. This distribution approximates that occurring in some of the photosynthesis experiments carried out with the dropping mercury electrode (6).

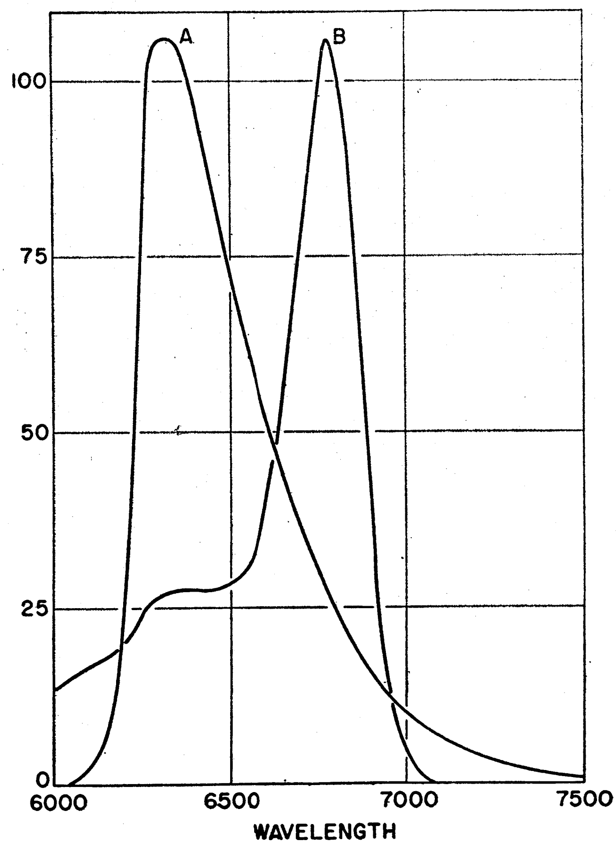


FIGURE 2. A, relative intensity distribution for a light source consisting of tungsten lamp (2800K) + Corning signal red filter (#243) + 20 cm. of 0.0125 molar $CuSO_4$ in $H_2O$.

B, absorption spectrum of acetone extract from *Chlorella* (Petering and Manning, unpublished data). Ordinates are proportional to extinction coefficients. The curve is displaced 200 Å toward longer wavelengths in order to approximate the absorption in the plant cell.

For purposes of calculation, the band of light represented by curve A in Fig. 2 was split into ten component wavelengths, each with a different absorption coefficient. Each component represents a band 100 Å in width, except for a 200 Å band at 6250-6450 Å ($k$ approximately constant in this range) and a broad band representing all light beyond 7050 Å (for which $k \cong 0$). Substituting into equations 1′ and 4′, it is found that a concentration and path-length, such that $I_s/I_o = 0.451$, results in an uncertainty value of 0.062, as compared with an uncertainty of 0.026 for monochromatic light having the same ratio of $I_s/I_o$ ($ks = 0.80$). For a 50% greater concentration of material, similar calculations give $I_s/I_o = 0.324$ and an uncertainty of 0.114 instead of the corresponding monochromatic uncertainty value of 0.050 ($ks = 1.13$). Thus, for a system covering a very large range of absorption coefficients, as in Fig. 2, the use of non-monochromatic light produces a considerable increase in the uncertainty associated with a given value of $I_s/I_o$.

## Conditions Favoring a High Value for Measured Rate at a Given Value for Incident Light Intensity

Frequently, in photochemical studies, the intensity of incident light is so low, either from necessity or from choice, that the principal source of error occurs in the measurement of the small resulting reaction rates. This is particularly true for reactions involving biological material, as does photosynthesis, where the time for a measurement must be kept small because of the other reactions inevitably associated with living matter. It is therefore desirable to determine the experimental conditions which will yield, for a given intensity of incident light, a near-maximum rate without causing excessive uncertainties in the measured value.

Where a dropping mercury electrode is used, the measured rate is markedly influenced by the concentration of light-absorbing material and by the depth of the reaction vessel.

### *Optimum value for the product ks*

Differentiation of equation 2 gives

$$dR_{s/2}/dk = \gamma' I_o e^{-ks/2}(1-ks/2) \qquad (6)$$

$$= 0 \text{ for } k = 2/s \text{ or for } ks = 2$$

Consequently, in the absence of mixing due to diffusion or convection, a maximum rate would be obtained for a concentration of material such that the product $ks$ is equal to 2.

But in the case of maximum mixing (equation 3 valid), the derivative becomes

$$dR_{s/2}/dk = \gamma' I_o e^{-ks} \qquad (7)$$
$$= 0 \text{ for } ks = \infty$$

Thus, in the limiting case where the rate of oxygen change is assumed to be equal throughout the reaction vessel, a maximum

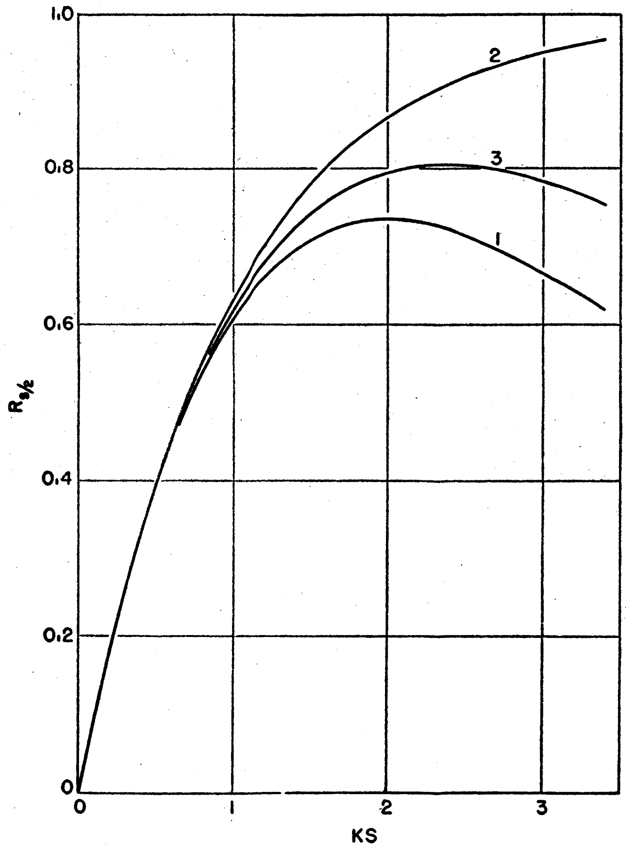


**Figure** 3. $R_s/_2$ as a function of $ks$ for monochromatic light. (1), (2) and (3) are calculated from equations 2, 3 and 5 respectively, assuming $\gamma = \gamma'$ $= \gamma_c$. The scale for $R_{s/2}$ is such that curve (2) approaches a value of 1.0 assymptotically as complete absorption is approached.

rate would be obtained only for complete absorption of the incident radiation.

Fig. 3 shows the effect of concentration on the measured rate for three cases: (1) no diffusion (equation 2 valid), (2) maximum diffusion (equation 3 valid), (3) intermediate diffusion such that equation 5 is valid. Here a constant quantum yield is assumed for each case, and the corresponding rate is calculated therefrom. Fig. 3 indicates that in an actual experiment, any value for $ks$ between 2 and 3 will give a value for $R_{s/2}$ near enough to the maximum for practical purposes.

Incidentally, the uncertainty defined by equation 4 is shown graphically in Fig. 3 as the difference in height between curve (2) and curve (1), divided by the height of curve (2). In adjusting the concentration of reactants to obtain a rate near the maximum, it must be remembered that the uncertainty range increases rapidly as $ks$ becomes larger than 2. In actual practice, because of the uncertainty factor, the maximum over-all accuracy for measurement of $R_{s/2}$ should be obtained at a concentration slightly less than that corresponding to maximum $R_{s/2}$. The greater the precision of the rate measurement, the lower will be the value of $ks$ necessary to give maximum accuracy, particularly for non-monochromatic light.

*The influence of path length on the measured rate*

In the case of no diffusion, substitution of $k = 2/s$ into equation 2 gives for a maximum rate

$$R_{s/2}\ (\text{max.}) = 2\gamma I_o/se \qquad (8)$$

Similarly, in the case of maximum diffusion, substitution of $ks = \infty$ into equation 3 gives for the maxium rate

$$R_{s/2}\ (\text{max.}) = \gamma' I_o/s \qquad (9)$$

In either case, the maximum rate is inversely proportional to the thickness, $s$, of the reaction vessel. The same relation should hold approximately for intermediate degrees of mixing.[2] Moreover, equations 2 and 3 indicate that the measured rate should

[2] The relation would not be strictly accurate for intermediate mixing. Any effects due to diffusion would increase in relative importance with decreasing $s$, since concentration gradients would be correspondingly increased.

show a similar dependence on $s$ for any constant value of the product $ks$.

In the photosynthesis experiments reported by Petering, Duggar and Daniels (6), $s$ was 1.6 cm. In more recent experiments in the same laboratory (3) $s$ was reduced to 1.0 cm. It is possible that for certain purposes somewhat thinner cells would prove still more satisfactory.

However, when $s$ is small and $k$ correspondingly large, the distance of the capillary tip from the windows must be known with greater accuracy than when $k$ is small (except for the limiting case of maximum mixing). This is evident from the following considerations.

If the maximum error in the location of the capillary tip is represented by $\pm\Delta x$, then, for the case of no mixing, equation 2 may be written

$$R_{(x\pm\Delta x)} = \gamma k I_0 e^{-k(x\pm\Delta x)} = \gamma k I_0 e^{-kx_e\pm k\Delta x}$$

The relative error in the value of $R_x$ may then be written

$$\text{Relative error} = \frac{R_x - R_{(x\pm\Delta x)}}{R_x} = 1 - e^{\pm k\Delta x}$$
$$\cong \pm k\Delta x \text{ (for } k\Delta x < 0.2) \qquad (10)$$

For example, in a given case it may be desired to have a value not greater than 1.5 for the product $ks$. Then if a 1.5 cm. vessel ($s = 1.5$) is used, and a concentration of reactants such that $k = 1.0$ for the particular wavelength employed (77.7% light absorption), the uncertainty in location of the capillary tip, $\Delta x$, should be not more than $\pm 0.04$ cm. if the possible error due to this uncertainty is to be not greater than 4.0%. If, for another experiment with similar reactants, $s = 0.75$ and $k = 2$, giving twice the previous measured rate for the same incident intensity, $\Delta x$ must be reduced to 0.02 cm. to keep the maximum uncertainty at 4.0%. However, if the first measured rate (for $k = 1$) were so low that it could be determined only with an accuracy of say 15%, it might be desirable to go to $s = 0.75$ and $k = 2$ even though $\Delta x$ were to remain constant at 0.04 cm.

In actual experiments, the requirements for a small $\Delta x$ should be somewhat less vigorous than those developed above, since diffusion and convection would tend partially to equalize the rate of oxygen change throughout the reaction vessel.

*Effect of silvering the back window of the reaction vessel*

In experiments at low light intensities or where, for any other reason, absorption of a large proportion of the incident light is necessary or desirable, it may, in certain cases, be advantageous to use a vessel in which the back window is externally silvered, to give total reflection of the light which otherwise would be transmitted. This type of vessel makes additional light available for reaction and at the same time reduces the difference in intensity between the front and back windows. For a silvered vessel, equation 1 is replaced by the equation

$$I_x = I_{\text{incident}} \left[ e^{-ks} + e^{-ks} e^{-k(s-x)} \right]$$

$$= \frac{2I_{\text{incident}}}{e^{ks}} \cosh \left[ k(x-s) \right]$$

Thus, for a concentration which, in a non-reflecting vessel, would absorb 75% of the incident light, giving $I_{s/2} = 0.5\ I_{\text{incident}}$ and $I_s = 0.25\ I_{\text{incident}}$, a silvered vessel would give $I_o = 1.06\ I_{\text{incident}}$, $I_{s/2} = 0.625\ I_{\text{incident}}$ and $I_s = 0.50\ I_{\text{incident}}$. For concentrations giving less complete absorption, the improvement would be even more marked. The formula for uncertainty due to diffusion and convection as a function of $ks$ (equation 4) turns out to be the same for silvered as for unsilvered vessels. Thus the increased light for reaction is available without increasing the range for uncertainty.

The use of silvered vessels should be of greatest advantage in studies comparing reaction rates at different light intensities, since light intensity can be nearly equalized in all parts of a reaction vessel by this means. For example, a concentration of material giving a 20% variation in light intensity in an unsilvered vessel ($I_s = 0.8\ I_o$) would result in a variation of only 2.5% in a vessel with the rear window silvered, at the same time giving an increased reaction rate.

The principal disadvantage of a silvered vessel would be the increased difficulty of measuring the amount of transmitted light, but this might be overcome, either by leaving unsilvered a small portion of the rear window or by measuring the light transmitted by the same material in another vessel (or by using a cross-beam of light if the reaction vessel has optically plane sides and if the reaction mixture is a solution).

The preceding discussion has emphasized the sources of error involved in use of the dropping mercury electrode for the study of photochemical reactions. But if its limitations are recognized, and if the conditions leading to excessive error or uncertainty are avoided, the method can be used easily to obtain relatively accurate results, in many cases under conditions where other methods cannot be employed.

## SUMMARY

A dropping mercury electrode measures concentrations occurring in the immediate vicinity of the electrode tip, rather than total or average concentrations throughout a reaction vessel. In photochemical measurements, this characteristic produces an uncertainty in the measured rate. In general, this uncertainty is greater for polychromatic light than for monochromatic light. In either case, the uncertainty increases as the fraction of absorbed light is increased. Other factors influencing the accuracy of measurements with the dropping mercury electrode must be considered in relation to the uncertainty factor in the selection of optimum conditions for a given experiment.

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# HOST LIST OF THE GENUS *TRICHOMONAS* (PROTOZOA: FLAGELLATA*

## PART II, HOST-PARASITE LIST

BANNER BILL MORGAN

The first article of this series (Morgan, 1942) which appeared as a stencil circular, compilation No. 1, by the Department of Veterinary Science, College of Agriculture, comprised a parasite-host list in which the species of *Trichomonas* were listed, including original dates and authors. In Part 2 the species of *Trichomonas* are given after the names of their respective hosts. Hosts are listed by Phyla, Classes, Orders, and Families to facilitate a comprehensive view of host parasite relationships.

The writer is deeply indebted to Dr. H. Kirby, Department of Zoology, University of California, and Dr. D. H. Wenrich, Department of Zoology, University of Pennsylvania, for kindly checking the manuscript. Acknowledgments are due also to Dr. L. E. Noland and Dr. C. A. Herrick, Department of Zoology, University of Wisconsin, for helpful suggestions. In a work of this kind errors are bound to occur. The writer invites correspondence concerning omissions or errors.

### COPROZOIC

Human feces—*T. fecalis*

### INVERTEBRATA
### MOLLUSCA

Order Pulmonata (Limacidae)
    *Limax agrestis* (land snail)—*T. limacis.*

* Contribution from the Department of Veterinary Science, University of Wisconsin. Published with the approval of the Director of the Wisconsin Agricultural Experiment Station. Project No. 622-V; Trichomoniasis and other reproductive diseases of cattle; B. A. Beach (In Charge), W Wisnicky, cooperating.

### ANNELIDA

Order Gnathobdellida (Hirudinidae)

*Haemopis sanguisuga* (horse leech)—*T. sanguisugae, T. prowazeki.*

*Limnitis turkestanica* (leech)—*T. ninae kohl-yakimovi.*

### ARTHROPODA

Order Isoptera

(Hodotermitidae)

*Hodotermes mossambicus* (termite)—*T. macrostoma.*

*Anacanthotermes murgabicus* (termite)–*T. vermiformis.*

(Kalotermitidae)

*Anacanthotermes murgabicus* (termite)–*T. vermiformis.*

*G. contracticornis* (termite)—*T. cartagensis.*

*Calcaritermes brevicollis* (termite)—*T. brevicollis.*

*Neotermes holmgreni* (termite)—*T. holmgreni.*

*Archotermopsis wroughtoni* (termite)—*T. termitis.*

(Rhinotermitidae)

*Rhinotermes* sp. (termite)—*T. termitidis.*

*Reticulitermes lucifugas* (termite)—*T. trypanoides.*

(Termitidae)

*Mirotermes hispaniolae* (termite)—*T. labella.*

*Amitermes minimus* (termite)—*T. lighti.*

*A. emersoni* (termite)—*T. lighti.*

*A. silvestrianus* (termite)—*T. lighti.*

*A. coachellae* (termite)—*T. lighti.*

*A. wheeleri* (termite)—*T. lighti.*

*Orthognathotermes wheeleri* (termite)—*T. linearis.*

*Termopsis angusticollis* (termite)—*T. termopsidis.*

*T. nevadensis* (termite)—*T. termopsidis.*

*T. laticeps* (termite)—*T. termopsidis.*

Order Orthoptera (Gryllidae)

*Neocurtyla* sp. (Probably *Neocurtilla* = *Gryllotalpa*) (mole cricket)—*Trichomonas* sp.

### VERTEBRATA
### PISCES

Order Teleostei (Sparidae)

*Box salpa* (sea bream)—*T. prowazeki.*

Order Percomorphi (Mullidae)

*Mugil capito* (mullet)—*Trichomonas* sp.

AMPHIBIA

Order Urodela

(Cryptobranchidae)

*Cryptobranchus alleganiensis* (hell-bender)—*T. angusta.*

(Salmandridae)

*Triturus torosus* (giant newt)—*T. augusta, T. prowazeki.*

*T. v. viridescens* (common newt)—*T. augusta, T. prowazeki.*

*Salamandra maculosa* (salamander)—*T. prowazeki.*

*S. salamandra* (spotted salamander)—*T. augusta.*

(Ambystomidae)

*Ambystoma maculatum* (spotted salamander)—*T. augusta.*

*A. opacum* (marbled salamander)—*T. augusta.*

*A. tigrinum* (tiger salamander)—*T. augusta.*

(Plethodontidae)

*Plethodon cincereus* (red-backed salamander)—*T. augusta.*

*P. glutinosus* (slimy salamander)—*T. augusta.*

*P. metcalfi* (salamander)—*T. augusta.*

*P. yonahlossee* (salamander)—*T. augusta.*

*Pseudotriton m. montanus* (salamander)—*T. augusta.*

*P. r. ruber* (salamander)—*T. augusta.*

*Eurycea b. bislineata* (salamander)—*T. augusta.*

*E. b. wilderae* (salamander)—*T. augusta.*

*E. gutto-lienata* (salamander)—*T. augusta.*

*Desmognathus f. fuscus* (dusky salamander)—*T. augusta.*

*D. o. ochropheaus* (salamander)—*T. augusta.*

*D. o. carolinensis* (salamander)—*T. augusta.*

*D. phoca* (salamander)—*T. augusta.*

*D. quadramaculatus* (salamander)—*T. augusta.*

*Triton cristatus* (salamander)—*T. prowazeki.*

*T. marmoratus* (salamander)—*T. tritonis.*

Order Anura

(Discoglossidae)

*Discoglosus pictus* (painted frog)—*T. duboscqui.*

*Alytes obstetricans* (mid-wife toad)—*T. prowazeki.*

(Bufonidae)

*Bufo calamita* (natter-jack toad)—*T. batrachorum.*

*B. melanosticus* (Asiatic toad)—*T. batrachorum.*

*B. vulgaris* (common toad)—*T. batrachorum.*

*B. fowleri* (Fowler's toad)—*T. augusta.*

*B. marinus* (giant toad)—*T. vitali.*

(Pelobatidae)

*Pelobates fuscus* (spadefoot frog)—*T. augusta.*

*Scaphiopus holbrooki* (spadefoot frog)—*T. augusta.*

(Ranidae)

*Rana catesbeiana* (bull-frog)—*T. augusta.*

*R. sphenocephala* (southern leopard frog)—*T. augusta.*

*R. esculenta* (edible frog)—*T. batrachorum.*

*R. pipiens* (leopard frog)—*T. augusta.*

*R. tigerina* (Indian bull-frog)—*T. batrachorum.*

*R. temporaria* (common frog)—*T. batrachorum.*

*R. viridis* (green frog)—*T. batrachorum.*

*R. boylei* (yellow-legged frog)—*T. augusta.*

*R. draytoni* (Pacific coast frog)—*T. augusta.*

(Hylidae)

*Hyla arborea* (European tree frog)—*T. batrachorum.*

*H. crucifer* (tree frog)—*T. augusta.*

*H. regilla* (tree frog)—*T. augusta.*

*Pseudacris brimleyi* (swamp tree frog)—*T. Augusta.*

(Leptodactylidae)

*Telmatobius gebski* (swamp frog)—*T. prowazeki.*

## REPTILIA

Order Chelonia

(Testudinidae)

*Geomyda trijuga* (Ceylon terrapin)—*T. brumpti.*

*Testudo radiata* (radiated tortoise)—*T. brumpti.*

*T. calcarata* (tortoise)—*T. brumpti.*

*T. argentina* (tortoise)—*T. brumpti.*

*T. hoodensis* (tortoise)—*Trichomonas sp.*

*T. elephantina* (tortoise)—*Trichomonas* sp.
*Cyclemys amboinensis* (box tortoise)—*Trichomonas* sp.

Order Crocodila (Crocydlidae)

*Crocodylus palustris* (marsh crocodile)—*T. prowazeki.*

Order Sauria (Suborder Lacertilia)

(Scincidae)

*Mabuia carinata* (skink lizard)—*T. lacertae, T. batrachorum.*

(Gekkonidae)

*Hemidactylus leschenaulti* (gecko)—*T. batrachorum.*

(Xantusiidae)

*Xantusia vigilis* (night lizard)—*T. lacertae.*

(Agamidae)

*Agama stellio* (starred lizard)—*T. lacertae.*

(Lacertidae)

*Lacerta agilis* (land lizard)—*T. lacertae.*
*L. muralis* (wall lizard)—*T. lacertae.*
*L. viridis* (green lizard)—*T. lacertae.*

(Anguidae)

*Auguis fragilis* (blind-worm lizard)—*T. alexeieffi.*

(Iguanidae)

*Dipsosaurus dorsalis* (crested desert lizard)—*T. lacertae.*
*Sauromalus obesus* (chuck-walla lizard)—*T. lacertae.*
*Uta mearnsi* (brush lizard)—*T. lacertae.*
*U. stansburiana* (brush lizard)—*T. lacertae.*
*Callisaurus ventralis* (zebra-tailed lizard)—*T. lacertae.*
*Sceloporus occidentalis biseratus* (collarded lizard)—*T. lacertae.*
*S. gracious vandenburgianus* (collared lizard)—*T. lacertae.*
*Phrynosoma blainvillei* (horned lizard)—*T. lacertae.*
*Uma notota* (sand lizard)—*T. lacertae.*

Suborder Ophidia

(Colubridae)

*Heterodon simus* (short-fat hog-nosed snake)—*Trichomonas* sp.
*Passerita (Dryophis) nasutus* (long-nosed snake)—*T. batrachorum.*
*Coluber (Elaphe) leopardinus* (leopard snake)—*Trichomonas* sp.

*Natrix natrix* (grass snake)—*Trichomonas* sp.
*N. erythrogaster* (water snake)—*Trichomonas* sp.
*Ablabes calamaria* (coluber snake)—*Trichomonas* sp.
*Drymarchon corais* (gopher-snake)—*Trichomonas* sp.
(Elapidae)
*Naja (Naia) naja* (Indian cobra)—*Trichomonas* sp.
(Boidae)
*Python sebae* (African python)—*Trichomonas* sp.
*P. molurus* (Indian python)—*Trichomonas* sp.
*Boa constrictor* (boa constrictor)—*T. boae, Trichomonas* sp.

AVES

Order Pelecaniformes (Phalacrocoracidae)
*Phalacrocorax a. africanus* (cormorant)—*T. hoarei.*
Order Anseriformes
(Anatidae)
*Anas rubripes tristis* (black duck)—*Trichomonas* sp.
*Nyroca marila* (scaup duck)—*Trichomonas* sp.
"Goose" (? *Anser. a. anser*)—*T. anseri.*
"Duck"—*T. gallinae, T. anatis.*
Order Falconiformes
(Accipitridae)
*Accipiter cooperi* (Cooper's hawk)—*T. gallinae.*
*Buteo b. borealis* (red-tailed hawk)—*T. gallinae.*
*B. l. lineatus* (red-shouldered hawk)—*T. gallinae.*
*Aquila chrysaetos canadensis* (golden eagle)—*T. gallinae.*
(Falconidae)
*Falco c. sparverius* (sparrow hawk)—*T. gallinae*
*F. peregrinus anatum* (duck hawk)—*T. gallinae.*
Order Galliformes
(Tetraonidae)
*Bonasa umbellus* (ruffed grouse)—*T. bonasae, Trichomonas* sp.
*Perdix p. perdix* (European partridge)—*T. ortyxis, T. hegneri, T. floridanae var. perdicis.*
(Phasianidae)
*Gallus g. domestica* (domestic chicken)—*T. gallinae, T. gallinarum, T. eberthi.*

"valley quail"—*T. floridanae, T. ortyxis.*
*Phasianus torquatus* (ringed-necked pheasant)—*T. phasiani.*
*Colinus v. virginiana* (bobwhite quail)—*T. gallinae, T. phasiani, T. floridanae var. colini.*
*Lophortyx c. californicus* (California valley quail)—*T. floridanae, T. hegneri.*

(Numididae)
*Numida meleagris* (guinea-fowl)—*T. gallanarum.*

(Meleagrididae)
*Meleagris gallopavo* (turkey)—*T. gallinae, T. gallinarum.*

Order Gruiformes
(Aramidae)
*Aramides cajanea* (cayenne wood rail)—*T. avium.*

(Rallidae)
*Fulica a. americana* (American coot)—*T. fulicae.*
*Porzana carolina* (sora rail)—*T. porzanae.*

Order Charadriiformes
(Scolopacidae)
*Pisobia minutilla* (least sandpiper)—*T. pisobiae, Trichomonas* sp.
*P. melanotos* (pectoral sandpiper)—*T. pisobiae.*
*Ereunetes pusillus* (semipalmated sandpiper)—*T. pisobiae.*
*Erolia alpina* (stint)—*T. sigalasi.*
*Calidres leucophaea* (knot)—*T. landei.*

Order Columiformes
(Columbidae)
*Columba livia* (domestic pigeon)—*T. gallinae.*
*Streptopelia risoria* (ring-dove)—*T. gallinae.*
*Zenaidura carolinensis* (mourning dove)—*T. gallinae.*
*Leptotila v. verrauxi* (white-bellied dove)—*T. gallinae.*
*Turtur suratensis* (Indian dove)—*T. gallinae.*

Order Psittaciformes (Psittacidae)
*Brotogeris jugularis* (tovi parrakeet)—*T. gallinae.*

Order Cuculiformes
(Cuculidae)
*Crotophaga ani* (ani)—*T. avium.*
*Guira guira* (guira cuckoo)—*T. avium.*

*Coccyzus a. americana* (yellow-bellied cuckoo)—*T. coccyzi, T. beckeri.*

Order Strigiformes (Strigidae)

*Otis asio* (screech owl)—*T. oti.*

Order Caprimulgiformes (Caprimulgidae)

*Podager nacunda* (nacunda nightjar)—*T. lanceolata.*

*Chordeiles minor* (night-hawk)—*T. chordeilis, T. iowensis.*

Order Piciformes (Galbulidae)

*Monasa nigrifrons* (nunbird)—*T. avium.*

Order Passeriformes

(Ploceidae)

*Munia oryzivora* (Java sparrow)—*T. gallinae.*

*Passer d. domesticus* (English sparrow)—*T. gallinae.*

(Fringillidae)

*Serinus canaria* (canary)—*T. gallinae.*

(Corvidae)

*Corvus b. brachyrhynchos* (Eastern crow)—*T. corvus.*

## MAMMALIA

Order Marsupialia

(Didelphiidae)

*Didelphis v. virginiana* (opossum)—*T. didelphidis.*

(Macropodidae)

*Macropus* sp. (kangaroo)—*T. macropi.*

*M. brunii* (rock kangaroo)—*T. macropi.*

*M. robustus woodwardi* (Woodward wallaroo)—*T. macropi.*

*M. melanops* (black faced kangaroo)—*T. macropi.*

*M. g. giganticus* (great gray kangaroo)—*T. macropi.*

*Dendrolagus ursinus* (black tree kangaroo)—*T. mcaropi.*

Order Primates

(Hylobatidae)

*Hylobates hoolock* (hoolock gibbon)—*Trichomonas* sp.

(Cercopithecidae)

*Macacus irus* (crab-eating monkey)—*Trichomonas* sp.

*M. sinica* (toque monkey)—*Trichomonas* sp.

*M. mulatta* (Rhesus monkey)—*T. macacovaginae, Trichomonas* sp.

*M. lasiotis* (hairy-eared monkey)—*Trichomonas* sp.
*M. nemestrina* (pig-tailed monkey)—*Trichomonas* sp.
*M. philippinensis* (Philippine Rhesus monkey)—*Trichomonas* sp.

(Pongidae)
*Pongo pygmaeus* (orang utan)—*Trichomonas* sp.
*Pan* (*Anthropopithecus*) *satyrus* (chimpanzee)—*T. anthropopitheci, Trichomonas* sp.

(Hominidae)
*Homo sapiens* (human)—*T. tenax, T. hominis, T. vaginalis.*

Order Edentata

(Myrmecophagidae)
*Tamandua tetradactyla* (tamandue anteater)—*T. aragaoi.*

(Dasypodidae)
*Tatus* (*Dasypus*) *novemcinctus* (nine-banded armadillo) —*T. tatusi.*

Order Rodentia

(Sciuridae)
*Marmota monax* (woodchuck)—*T. cryptonucleata, T. digranula, T. marmotae, T. wenrichi.*
*Cynomys* sp. (prairie-dog—*T. cynomysi.*
*Citellus pygalus* (ground squirrel)—*T. muris var. citelli.*
*C. tridecemlineatus* (thirteen-striped ground squirrel)—*T. muris var. citelli.*

(Muridae)
"white rat"—*T. guiarti.*
*Apodemus sylvaticus* (wood mouse)—*T. muris.*
*Rattus norvegicus* (brown rat)—*T. parva, T. muris, T. minuta.*
*Mus musculus* (house mouse)—*T. parva, T. muris, T. minuta.*
*Myotomys albicadautus* (white-tailed rat)—*T. mystromyis.*
*Cricetulus furunculus* (Daur hamster)—*Trichomonas* sp.
*Rhombomys opimus* (Jerboa-like rodent)—*Trichomonas* sp.

(Erethizontidae)
*Coendou villosus* (hairy-tree porcupine)—*T. megastoma.*

(Hystricidae)

*Hystrix bengalensis* (Indian porcupine)—*Trichomonas* sp.

(Caviidae)

*Cavia coboya* (guinea pig)—*T. caviae.*

*Kerodon* (*Cerodon*) *rupestris* (rocky cavy)—*T. chagasi.*

(Cricetidae)

*Ondatra z. zibethica* (muskrat)—*Trichomonas* sp.

*Evotomys glareolus* (bank vole)—*T. muris.*

*Microtus arvalis* (field mouse)—*T. muris.*

*M. hirtus* (field mouse)—*T. muris.*

*Peromyscus maniculatus gambeli* (white-footed mouse)—*T. muris.*

*P. l. leucopus* (white-footed mouse)—*T. muris.*

*Neotoma fuscipes* (wood rat)—*Trichomonas* sp.

*Pitymys* sp. (pine mouse)—*T. lavieri.*

Order Carnivora

(Canidae)

*Canis familiaris* (dog)—*T. canistomae, T. felis, Trichomonas* sp.

*Vulpes regalis* (Northern plains red fox)—*Trichomonas* sp.

(Viverridae)

*Herpestes auropunctatus* (spotted mongoose)—*Trichomonas* sp.

*H. mungo* (mongoose)—*Trichomonas* sp.

(Felidae)

*Felis domestica* (cat)—*T. felis, T. felistomae.*

Order Perissodactyla

(Equidae)

*Equus caballus* (domestic horse)—*T. equi, T. equibuccalis, Trichomonas* sp. (vagina, uterus).

(Tapiridae)

*Tapirus ralinus* (tapir)—*T. tapiri.*

Order Artiodactyla

(Suidae)

*Sus scrofa domestica* (domestic pig)—*T. suis, Trichomonas* sp. (face), *Trichomonas* sp. (vagina, uterus).

(Cervidae)

*Capreolus capreolus* (roe deer)—*Trichomonas* sp. (vagina, uterus).

(Bovidae)

*Bos taurus* (domestic ox)—*T. foetus, T. ruminantium.*

*B. indicus* (domestic humped ox)—*T. ruminantium.*

*Ovis aries* (domestic sheep)—*T. ovis, T. ruminantium, T. foetus.*

*Capra hircus* (goat)—*T. ruminantium.*

# GEOLOGICAL CONTRIBUTIONS TO HUMAN PROGRESS

RUFUS MATHER BAGG

## PART I

*Geology.*

*Geology*, the latest technical science to be devoloped through experiment, treats of the *History of the Earth and its Inhabitants.*

Alchemy, antedating Chemistry, centered its efforts on the transmutation of metals.* Astrology, preceding Astronomy, devoted attention to the influence and control of Stars over man's activities; while Philosophy and speculative study of terrestrial phenomena gave birth to Geology, dealing with physical changes and of fossil organisms which have inhabited the earth since the creation of life.

Natural Sciences were unknown in days of pagan philosophy, 2,600 years ago. Superstition reigned supreme. Even 300 years before the Christian era, Aristotle, the gifted pupil of Plato, explained the discovery of fossil fish, petrified in solid rocks, as due to the subtle influence of the stars. He named this force, "*Vis plastica*" and believed the development from eggs in rocks had been greatly retarded owing to their hard environment. He did not understand that these fish were once living in an ocean and upon their death were buried in muds millions of years ago.

These superstitions and philosophical speculations concerning all sorts of natural phenomena continued to the dawn of modern history.

Even in the Middle Ages, volcanic eruptions were regarded

* From astounding discoveries in the physics laboratory during the past few years it appears almost certain that the Alchemist's dream has at last come true. According to Dr. Millikan, silver has been bombarded until its atoms have turned to cadmium, and it is reported that mercury can be transformed into gold, though neither of these changes are yet of commercial value.

as the expression of the wrath of some Deity. Explosive Etna and Vesuvius were places of perpetual punishment and emblems of eternal fire. As Pluto (Vulcan) ruled the lower world, so Neptune governed the Sea, unchained the storm and caused the ocean waves. When subterranean furnaces poured molten lava from fissures and craters of active Mediterranean volcanoes, Jupiter hurled his thunderbolts of lightning from the heavens above to complete the destruction of the Gods.

In that remote time Fear of punishment by angry Gods ruled the civilized world. To investigate the earth's cataclysmic phenomena was sacrilegious and certain to result in suffering if not in death. Antiquity contributed little therefore of permanent value to Geological Science.

Countless speculations and philosophic theories gave rise to varied hypotheses concerning the *Origin* of the earth. To ancient philosophers the Earth was the center of the Universe, around which all planets and stars revolved. No scientific interest was shown in the composition of rocks and minerals, and none understood the significance of petrified organisms which had long been observed in widely separated regions. In fact, 2,000 years ago the most highly educated did not dream of the importance of fossils nor realize that they afford the key which unlocks the History of the Earth through past ages. The ancient world trembled before the natural forces of Earthquake, Fire, and Wind, which they could not control.

With this brief survey of philosophic conceptions culminating about the time of Christ let us turn to the field of modern Geology.

## *Scope of Modern Geology.*

Like other physical and natural sciences, Geology touches several very distinct fields. She is particularly indebted to Biology for the foundation and classification of plants and animals in their relation to fossil organisms; (Paleontology), to Chemistry for analysis of rocks and minerals; to physics for geophysical instruments used in prospecting for oil and gas pools; and from Mathematics, Geologists calculate astronomic phenomena and the laws which govern celestial motions.

*Paleontology.*

Paleontology, or the study of organisms which have inhabited the Earth in past eras, is an important branch of Geology and closely related to Stratigraphy from which we read the record of earth history since life began more than one hundred million years ago.

The value of a fossil depends upon the fact that during every period of terrestrial development, there lived certain groups of characteristic organisms which had never existed before and which became extinct in succeeding epochs. From these ancestral forms, however, advanced and diversified life arose, but each era had peculiar types of fossils which can be used to decipher the geological ages of sedimentary rocks in which these animals have been entombed. The silent testimony of the fossil buried in solid rocks was rightly sensed by the poet who wrote:*

"There they lived out their gleam of life and died,
Then slowly drifted down into the dark,
And spread in layers upon the cold sea-bed,
The invisible grains and flakes that were their bones.
Layer upon layer of flakes and grains of lime,
Where life could never build, they built it up,
Inch upon inch, age after endless age."

*Contributions of Fossils to Human Knowledge.*

All life has its beginning, culmination, and death. This is true of individual organisms, of genera, and whole orders to which they belong. We may term this the "SPAN OF LIFE" and limit it to the individual species, like Man (Homo sapiens) or to a larger group of related organisms like the Mammals to which Man himself belongs.

Longevity of life is only a factor however, for we are thinking in terms of when the organism was developed, how long its type remained on earth, and when it became extinct. This is Paleontology's supreme contribution to human knowledge. Every period from Cambrian to Recent has seen new groups of

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* Alfred Noyes.

organisms originate, while older forms diminished in numbers and either quickly or gradually became extinct.

The *Graptolites* illustrate this truth.

*Graptolites.*

Probably the most striking case of the rise, culmination, and rapid decline of a group of organisms in ancient time is found in Graptolites, which were among the first to culminate, and the first to become extinct.

These tiny colonial animals whose skeleton resembles a blade of grass with serrate edges, first appeared at the close of Cambrian time in the "Age of Trilobites." Their dark charcoal-like markings occur widely scattered through Ordovician limestones of the Fox River Valley, Wisconsin, where they are identical with species from the Hudson River Shales of New York. We know therefore, that while the eastern shale beds were being deposited, identical forms were contemporaneously buried in lime muds of Wisconsin oceans.

Their geologic value lies in the fact that many *species* of Graptolites are limited to beds of only a few feet in thickness, when other types succeeded them. Thus they become CHARACTERISTIC FOSSILS of particular formations and because of universal distribution in early Paleozoic time they are horizon markers which identify stratified rocks perhaps thousands of miles apart.

The discovery that changes continually take place both in the Earth and its inhabitants is not new, but the *causes* of such phenomena were never correctly interpreted by ancient philosophers before the age of experimental science. Primitive doctrines of both Egyptian and Greek philosophy assigned the Creation of the World to an Omnipotent Being who existed from eternity, but they believed that He had repeatedly destroyed great groups of organisms through a series of terrestrial cataclysms. Today Geologists know that there has always been a very orderly progression of terrestrial changes and life evolutions interrupted only by local catastrophes, never from universal Deluges.

While reptilian life culminated with the gigantic Dinosaurs of the Mesozoic, nevertheless modern mammalian whales rival in length, if not in size, these monsters of the past. Not far from Dallas, Texas, we saw the skeleton of a dinosaur which had just been dug out of the Eagle Ford shale and we will not soon forget that sight. His long crocodilian head, inset with cruel four inch conical teeth lay twisted sidewise in perfect preservation while the serpentine neck nearly twenty feet long extended down the ditch in Cretaceous muds just as he had stretched out in death some thirty million years ago.

How long could such monsters have existed as a race and as individuals? Why did such powerful huge reptiles become extinct? Could it be that their food supply was exhausted? Certainly not, when medieval oceans were teeming with innumerable organisms approaching their own culmination. Was it a single cause which destroyed all? It is exceedingly doubtful.

Would climatic factors account for their total extinction? Possibly, for reptiles are sensitive to extremely low temperatures and either hibernate or migrate to warmer regions when cold approaches.

All the former crocodiles living in the far west when this great Dinosaur was swimming in a Texas Ocean have entirely disappeared, leaving only a few skeletal bones to prove their existence. Perhaps these monsters became so over-specialized that they could not adapt themselves to elevating lands, deepening seas, changing vegetation, and sudden climatic variations.

With extinction of Dinosaurs enormous masses of volcanic rocks began to erupt in the Rocky Mountains and covered 200,000 square miles in the far northwest. All the above causes therefore, or any single one, were the agents that resulted in such a catastrophe to Mesozoic life but which was later destined to be of direct benefit to Man.*

Many years ago we dug out Dinosaurian footprints in the Triassic sandstones of the Connecticut Valley, Massachusetts. These tracks were made when reptiles walked tidal flats of hardening muds near the margin of a medieval ocean. What can be learned from such impressions petrified in stone?

A sandstone slab, now in Yale Museum, shows where a Dinosaur walked along the ocean shore. The line between his foot-

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* Petroleum pools furnishing essential fuel and power to modern civilization are due to this prolific fossil life so that the trade mark of Sinclair Oil Co. using Brontosaurus as their mascot is not founded on fiction.

prints is cracked indicating how quickly the mud was hardening between tides. Less than six hours later a related monster crossed the same strand, but diagonally. Between this brief interval occurred a light shower, for raindrop impressions cover the footprints of the first Dinosaur but not those of the second. This is not all however, that geologists learn for these rain prints are elliptical and hence mark the direction the wind was blowing in that epoch many million years ago.

From such mud-cracks, sun-dried beaches, with ripple marks and wave-cut cross-bedded sands geologists read the location of the ocean shore, depth of water, and the relation of sea and land which the natural world reveals to the scientist like an open book.

When the great Reptiles ruled the Medieval World, countless millions of smaller invertebrate animals existed before and during this same era but in the older formations they seldom formed thick masses of sedimentary rocks. It is not always the giants which count most in the world, but often animals of microscopic size. For example, tiny organisms, like the Radiolaria, Diatoms, and especially the *Foraminifera,* have built up rocks of very great thickness, even of several thousand feet, and yet they are so small they must be studied with a microscope. Such a formation is the Cretaceous chalk composed chiefly of foraminiferal shells whose descendants constitute oceanic ooze covering fifty million square miles of existing sea bottoms down to 2,000 fathoms.

When we studied these minute fossils in the Greensands of New Jersey for a thesis we had no idea that they would ever have commercial value. Because they occur in oil-bearing formations where they are characteristic fossils they enable Geologists to identify the rock horizons in which they occur. When absent, petroleum engineers must use calculations based on structural folding, or resort to identification of heavy minerals, like zircon, to determine the formation the drill is cutting.

Summarizing the contributions of Paleontology to Historical Geology and world knowledge we find:

1. Fossils enable us to determine what types of life existed in every age of earth history and to discover the evolution, distribution, and extinction of each group of organisms.

2. They furnish positive proof of climatic conditions in ancient periods.

For example, coral reefs in Niagara Limestone near Bailey's Harbor, Wisconsin, though deposited in tropical waters of a Silurian ocean are worn today by the blue fresh water waves of Lake Michigan.

3. Fossils are often of economic value in determining in what rocks and where, oil, gas, coal, and other useful products may be expected.

4. Organic remains reveal the relations of sea and land, depth of oceans, migrations of animals, not only from one region to another, but over continents widely separated by ocean abysses of today.

5. Fossils are of inestimable value to Biologists as they show critical organic relationships revealing the origin of modern forms from archaic types.

6. The fossil world affords most unmistakable evidence of the *Time Factor* upon which all knowledge of earth history is based.

In the middle of the Tertiary period there was deposited at Pope's Creek, along the Patuxent river a bed of fossil Diatoms thirty feet in thickness. These microscopic shells are so minute that it takes some thirty million frustules to make one cubic inch of diatom earth, and under favorable conditions these diatoms can form a layer one-sixteenth of an inch thick in *one* year. If fossil diatoms were deposited at the same rate then it required 5,760 years to form the Pope's Creek deposit. Since this is but a fraction of the total thickness of the Miocene formation we gain some conception of the length of earth history since the creation of life.

7. Organic remains preserved and altered in sedimentary rocks give rise to extensive economic products essential to world progress. (Petroleum, gas, fossil limestones, coal beds, diatom earth, chalk, phosphates, etc.)

While many groups of organisms have become extinct we cannot believe that further life changes will not occur nor that they have culminated with the coming of Man.

From 100 to 300 million years must have elapsed since life was created and while a few initial forms like the little bivalve, Lingula, still exist in modern seas innumerable millions of its ancestors have risen, culminated, and are now extinct. Perhaps immortality is to result from extension of this *Span of Life* and from renewal of organic types evolving from primitive creations. It is hard to believe that Man, himself, can never make further physical, mental, or moral development, and that having reached culmination he must retrograde. If new organisms can develop as they have through all past ages there would seem to be no more end of life upon earth as long as it continues a Planet in our Solar System.

## PART II

*Economic Geology.*

As fossils reveal the record of organic life through past eras, increasing human knowledge of Earth History, so discoveries of mineral deposits through geologic engineering bring direct benefits to civilization.

From the financial standpoint, Economic Geology has become an important factor in welfare of nations. What are these essentials to human progress?

Engineering relates to successful solution of industrial problems. Without engineering skill the world's greatest enterprises could not have been completed. Neither pyramids in Egypt, the Panama Canal, nor Boulder Dam were possible without application of engineering principles.

Rapid changes occur in all branches of scientific knowledge but none have been more pronounced than those of geologic and mine engineering. We are still in the age of discovery, made possible through new inventions of instruments which furnish the keys to petroleum reservoirs, discovering ore deposits, rare elements like radium, and also determining the composition and character of the Earth's crust and its structures down to great depths and over wide regions. Through scientific investigations in mining geology with new technical instruments time is saved, wealth of natural resources increased, and human progress made more rapid.

Perhaps the most remarkable recent advance in economic geology has been obtained through Geophysical prospecting which discovers oil and gas reservoirs before drilling, or locates artesian water horizons, rock densities, and structural fault planes, many of which are not known from surface outcrops. During 1935, such geophysical work with magnetic surveys in the Kaibab plateau of Arizona indicated a structural trough in the Kaibab limestone which had been filled deeply with Tertiary water-bearing gravels. Below this upper zone moreover, and at great depth, a second greater artesian supply was discovered in a synclinal depression of the Coconino Sandstone. Only time and the slow pounding drill working all summer long could have deciphered such hidden rock conditions and structural basins.

Twenty years ago where surface conditions gave no indication of concealed oil pools in structural folds thousands of feet deep only experimental drilling could determine their location. Today, delicate torsion balances, seismographs, magnetometers, and other electrical instruments enable geologists to detect differences in rock densities and thus to locate mineral deposits and oil reservoirs before a well is spudded in.*

The buried mountain range in west Texas, never seen by human eyes, was located by means of the above instruments and its outline and extent later defined by drilling the basal slopes for oil and gas.

In 1929 on the Rand of South Africa we were told that geophysical investigations suggested considerable extension of the gold-bearing conglomerate reefs and that they were to be tested by the diamond drill. Successful termination today of these initial experiments have added many decades to the gold reserves of South Africa.

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* In 1934 there were 90 geologist parties using seismographs, 40 the torsion balance, 10 magnetometers, and three used gravimetric instruments. The number is increasing and magnetometer and electric resistance machines predominate.

The seismograph, devised originally for recording earthquake shocks has proved of value in other fields beside those mentioned in Economic Geology.

In Hawaii it aids in forecasting dangerous volcanic eruptions. When Mauna Loa began her explosions in late 1935 they had been predicted by the Vulcanologist, Dr. Jagger, from the increasing intensity of earthquakes recorded on the seven seismographs distributed over the island. Molten lavas flowing fourteen miles down the crater of this huge volcano were watched from above the steam clouds by airplane, photographed two miles over the crater, and bombed on terminal lava streams to prevent their further flow which threatened Hilo's city water supply. These seven seismographs made possible the prediction of an eruption which came in spite of native Hawaiian prayers to the goddess Pelé to save their people from further destruction. Man cannot prevent these terrestrial explosions but until recently it was not even possible to foretell their coming and to ward off their destruction.

Through these physical instruments three oil pools of magnitude were discovered in 1934 in the interior of Russia, in Colombia, S.A. and a third in the Jurassic rocks of Morocco near Tselfat.*

Although the basis of scientific progress today rests largely on small laboratory experiments, the geologic laboratory lies in the mountain, the Grand Canyon, or the Glacial-covered Alpine peaks, like "Old Mont Blanc" of whom the poet wrote:

"Mont Blanc is the Monarch of Mountains,
They crowned him long ago,
On a throne of rocks, in a robe of clouds
With a diadem of snow." (*Lord Byron.*)

Not all economic geology investigations however, are in the open field and as in other sciences much is learned by miniature experiment in the lowly laboratory. For example, a Mineralogist studies a rock in thin section under polarized light, not only to determine its component minerals, but the nature of the rock and its ultimate origin. By this slow method and application of physics to geology we know the origin of the Hawaiian Islands. It may seem strange that such microscopic study proves that this land of paradise is built entirely of homogeneous lavas, that the region was never connected with other continents, and that its eruptive basalts rise in mid-Pacific ocean three miles in depth and from a fissure over 300 miles in length.

The petrographic microscope has been of value in deciphering rock mineralization and in enrichment of ore deposits. When the late Prof. James E. Talmage of Utah was investigating a mine involved in lawsuit he discovered that adjacent ore had been stolen and the stopes back-filled with limestone transported to the mine from a distance. Microscopic study revealed the source of the limestone and the Court sustained the geological evidence.**

When an Appleton soldier was in France during the world

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* In 1935 the new oil reserves discovered in the United States are estimated to be from 1½ to 2 billion barrels. About ½ of these were in geological structures discovered by geophysical prospecting methods.

** As a result, Talmage was threatened but he took the personal risk and reported the truth of his findings.

war he sent his mother a piece of limestone from his dugout. She asked me if it would be possible from this to tell where her son was located. From the foraminiferal shells we identified the rock as Eocene and on the Geological map of France found where this belt crossed the country and thus gave her his approximate location.

*The Use of Ultraviolet Light in Mining.*

The use of ultraviolet light for discovery of Scheelite, an important Tungsten ore, presents a recent adoption of a physical instrument as an aid in geologic engineering.

Fluorescence, phosphorescence, and radio-active emanations have long been known and used in the laboratory to illustrate unique properties of certain minerals. Until recently however, such luminosity has never been of commercial value.

The ultraviolet lamp for detecting fluorescence in Scheelite ore is of the "strong arc" type. When such radiation strikes tungsten ores they glow and become fluorescent with various colors and the darker the mine workings the more luminous the Scheelite.

These colors furnish therefore a means of rapid and accurate calculation of the amount of tungsten in the vein minerals. This is particularly important since Scheelite resembles other gangue minerals like calcite and barite or even milky quartz which are often present in these ores.

Even after the ore is mined and concentrated this instrument is of aid in determining the amount of Scheelite in the finds but it should be examined in the dark. The value of this ultraviolet lamp is greater since analysis of tungsten ore is a slow tedious laboratory process and the time saved by the lamp is an important mining factor. Vanderburg* says of this: "In the case of Scheelite the ultraviolet apparatus is more rapid than panning, and because of the greater area available for exposure gives a better average."

*Diamond Drilling.*

The diamond is the hardest substance known and the black poorly crystallized bort or carbonado is above the gem which

* Vanderburg, Wm. O. U.S. Bureau of Mines Circular I.C. 6873, Dec. 1935.

can only be cut by its own dust. The use of black diamonds for rock drilling began in 1863 when a French engineer, (Rudolph Leschot) tested rocks by this method in the Mont Cenis tunnel then under construction between France and Italy.

Six years later the diamond drill was used to locate a coal bed in the Appalachian mountains and was sunk to a depth of 750 feet near Pottsville. Diamond drilling for gold ore began in Canada in 1871 and this method is in universal use today.* The diamond drill is even more important than any geophysical prospecting work since the latter may fail from a number of unknown factors while the diamond drill core tells the exact underground conditions and the richness of the veins of ore penetrated.

Our experience with this device of rapid and relatively inexpensive geologic investigation began on the Cuyuna Range in Minnesota. From systematic drilling over forty acres and sampling each core we found the most economical location for a vertical shaft and the amount of iron ore available. Even before drilling began the iron ore body had been discovered and outlined by the magnetic dip needle which indicated commercial ore although not a pound of iron was within fifty feet of the surface.

In the summer of 1934 we examined gold veins on Elk Island in God's Lake, Manitoba, 400 miles north of Winnipeg. Two diamond drills were then working on adjacent property. It is significant that from the evidence obtained in these holes, the expenditure of one million dollars was undertaken. Within two years, a shaft was sunk, a power plant fifty miles distant completed, a reduction mill installed at mine, and in October, 1936 the first $30,000 gold brick was carried out by airplane. Such is the romance of mining made possible with the diamond drill cutting a rock core less than one inch in diameter. In contrast with small diamond drill cores for rapid prospecting of gold veins is the circular five foot boring sunk in 1935 to a vertical depth of 800 feet (1100 feet Feb. 10, 1936) at the Idaho-Maryland mine in Grass Valley, California. While this shaft was chiefly in a soft Serpentine rock the mechanical difficulties of lifting huge five foot cores in sections down to a depth of 800 feet was an engineering feat of importance.

* The Sudbury Diamond Drilling Co. in 1935 *cored* 45 miles (less 11 feet) a record achievement in boring and at an average cost of $2.50 per foot.

When first introduced geologists could not know whether deep drill borings were truly vertical or not but today a simple device* makes this deviation readable. By such an instrument the nickel ore body of the Frood mine at Sudbury was drilled with diamonds and the hole kept straight down to one-half mile in depth. (2,500 feet.)

An oil well drilled with a rotary rig in Texas, 5,000 feet in depth was scaled and its off-center deviations surveyed in one hour by a gyroscopic clinometer combined with a Sun-Sperry camera. These technical problems cannot be discussed here but we should know that modern inventions and engineering skill have made it possible to explore the earth's crust more than two miles below the surface.

*Deepest Borings in the Earth.*

The interior of the earth and its composition have long proved a most fascinating geologic problem which has been attacked from various angles.

Astronomic evidence indicates that the entire planet system, though varying in density, is of the same homogeneous composition. Not one meteorite which has ever fallen on the earth from outer space has ever shown other elements than occur in the earth and although twenty six elements are listed, native iron far exceeds all other substances. Since the rocky granite crust of the earth has a specific gravity of but 2.75 and the total weight of the earth shows a gravity 5.66 times that of water many have argued that the interior must be composed of metallic iron, perhaps in a semi-liquid condition.** Whether the center is theoretically gaseous or molten, yet potentially solid because of enormous pressure, is not known, but since earthquake shocks are conducted through 2,000 miles of the outer crust in a few seconds we know that the planet is a solid down to at least one-fourth its diameter.

That the interior is excessively hot, if not molten, is certain from the rapid increase of temperature from the surface downward. The rate is not less than one degree Fahr. for every fifty

* Tube containing a mixture of hydrofluoric acid and water for insertion in the machine in the hole. (Maas compass used chiefly in Canada)

** The weight of the Solid Lithosphere of the Earth is calculated at 6,585,868,000,000,000,000,000 tons.

to one hundred feet although not uniform in widely spaced locations. We experienced a temperature of 92° Fahr. at a depth of 6,100 feet in Johannesburg, S. Africa, which indicates a rise of only one degree for each 220 feet depth.

Whatever the actual condition we are certain that the earth's core is of high density, that the temperature is sufficient to transform its material were pressure removed into not only a molten magma but perhaps into gaseous substance like that of the outer envelope of the sun. Under most terrific compression forces however the sphere is held rigidly in its planet position in its journey through space acting like a ball of steel and incapable of serious deformation or chemical alteration.

*Deepest Exploration of the Earth.*

The subject of deep mining and drilling of the earth gives rise to the question frequently asked:—"What is the deepest boring in the world?" Before answering such a question we must define our terms. Do we mean the deepest artesian well, oil or gas boring, or the deepest mine shaft where men work more than one mile below the surface? If the latter, then we must measure the shaft vertically. For example, the Quincy No. 2 shaft at Calumet has a cable lift 8,360 feet long but the shaft inclines at high angle (54° changing to 36° at the bottom). Hence this is not as deep as the adjacent Tamarack bottomed at 5,309 feet or just over one mile vertically. Again shall we calculate these depths by shaft or drill from *Sea Level* or from whatever elevation they happen to occur? It was a surprise to me to learn that the curb shafts of the Johannesburg gold mines were measured from a datum plane 6,000 feet above the sea. When we walked therefore, along the bottom level of the Robinson Deep at a vertical depth of 6,100 feet we were only 100 feet below the level of the ocean waves.

The greatest mining depth in the world today is reached by the Turf shaft of the Village Deep, at Johannesburg which was bottomed in 1934 at 8,401 feet below surface and still going deeper though the temperature is almost 100 degrees Fahr. where air cooling devices are required.

It is interesting to speculate on how much deeper puny man can descend into the earth's crust digging out precious gold buried in massive rocks from two to three miles below the ground. South African geologists believe that the great conglomerate reefs can be mined down to 9,000 feet and perhaps to 10,000 while some talk of a limit of 12,000 feet. Factors yet unknown, beside increase of temperature, may prevent this. Terrific rock pressures, underground water, reduction of gold content in the ore, may necessitate abandonment of the workings long before the total known gold content is exhausted.* We should remember when speaking of great depth records that championships are always changing and that what we cite today may be out of date tomorrow.

With mine temperatures of almost 100° Fahr. both in Brazil and South Africa, with more than 40 shafts below one mile in depth, the closing days of the world's greatest gold mines must be approaching. However, as long as bonanza ore goes down two miles deep man will find a way to mine it. One thing is certain that when President Roosevelt increased the price of gold from 20 to 35 dollars an ounce he added 3,000 feet of profitable mining to the Rand conglomerate reefs.

*Petroleum and Gas Well Records.*

Great as are these depths of record gold mines where men work over one mile below ground they do not equal the borings for oil and gas, some of which today exceed two miles in vertical depth. Ten years ago drilling below 5,000 feet was considered a unique engineering feat. In 1931 three rotary rigs were coring rock around 10,000 feet below the surface. Two years later, in 1933, the Penn-Mex petroleum well at Vera Cruz was finished at 10,585 feet or 85 feet more than two miles, and a second was searching for an oil sand in the Caddo field of Oklahoma but gave up at 10,079 feet.

In June, 1935, not far from McCamey, Texas the Gulf Production Co. bottomed an oil project at 12,786 feet which as far we know was considered the world's record of man's search for

* Vying with the Transvaal gold mines in depth is that of Morro Velho (St. John del Rey) in Minas, Geraes, Brazil. Bottomed in 1932 at 8,040 ft. it is still being deepened and is paying dividends.

petroleum at a depth heretofore considered impossible.* Although the well was a failure the core was saturated with petroleum but salt and sulphur united to mix with ground water and the project was abandoned. The bottom temperature was reported to be 182.3 degrees Fahr. but only 149° at a depth of two miles.

When we consider the weight of drilling tools and cable in a 10,000 foot oil well which exceed 130 tons, to say nothing of the 150 ton casing of walls we gain some idea of the magnitude of the enterprise. To me such exploits mark the romance of subterranean exploration and yet we must admit that the downward limit of both shaft and rotary bit has not culminated. Much depends upon improved engineering mechanics, skill in overcoming interior heat, rock pressure, artesian water, and problems connected especially with hoisting difficulties.

### *Depths and Deposits of the Ocean.*

Long a student of oceanic deposits we have hoped that some day it might be possible to bore into the bottom of marine abysses far below that of the sounding machines which have already brought priceless information of the deposits on the sea floor down to a depth of six miles.**

In the laboratory we have examined oceanic ooze, marine muds, and organic deposits from every ocean but until recently no one has been able to bore deep into these to determine their character and thickness. Modern inventions now make it look as if our dream may come true. The latest device for such experimentation consists of a long sharply pointed cylinder above which at the cable junction it is possible to explode a charge of dynamite the moment the tube touches bottom. The force drives the cylinder a few feet into the bottom material and when brought to the surface furnishes a core exactly like that of a diamond drill.*** This work is yet in experimental stage but at a

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* Since this address was written petroleum wells have been sunk much deeper. In 1938 the Continental Oil Company's well near Wasco, Cal. was drilled to 15,004 feet below the surface for a world record.

** Dr. Paul Bartsch is working on an improved type of a machine which will prove more efficient and which can be used at much greater depths.

*** Greatest known depth is 35,400 feet according to Nat. Geog. Mag. Map Dec. 1935. Only 145 miles southeast of Tokio a depth of 32,644 feet is recorded and in the North Atlantic, off Porto Rico a sounding of 31,366 feet has been measured.

depth of many hundred fathoms a core of solid pteropod (ooze) limestone has been brought to the surface revealing that this ooze of the North Atlantic is of considerable thickness. The average elevation of terrestrial land is estimated at 2,750 feet but that of the oceans is 12,300 feet, or just over two miles, so that the seas are nearly five times deeper than the lands are above sea level and at least in three places these deeps exceed six miles.

Since many of the great oceanic deposits are quite different from the materials forming the major portion of sedimentary rock formations which compose the outer crust of the earth it is essential that we know more concerning these marine formations which are slowly accumulating at vast depths below the surface of the sea. When we find minute fragments of star dust, volcanic ashes, and unique minerals in these marine oozes we long to know their thickness below the ocean floor and the rate of formation which has such an important bearing on the origin and the age of the earth. From geologic investigations cited above and along new lines of attack we are certain to acquire important data of the History of the Earth and the potential wealth which man has not yet been able to uncover.

### *Aviation in Geologic Engineering.*

Rapid transportation of man and heavy freight through the air is a modern miracle.* The airplane has annihilated distance in all parts of the earth. Every day gigantic planes are flying from 100 to 400 miles an hour, over land and sea, above forest and desert, in arctic cold and tropic heat, carrying men and supplies with reasonable safety, economy of time, and at increasingly lower cost.

The airplane is a novelty in heavy freight transport through the atmosphere but of astounding importance in handling ore and mine supplies quickly over uncharted lands and hitherto inaccessible regions. Tons of freight today are regularly carried 100 miles in one hour and at a cost of less than ten dollars for fuel.

* In January 1936 Howard Hughes flew from Burbank, Cal. to Newark, N.J. in 9 hrs. 25 min. 10 sec. in a Northrop "Gamma" plane.

The best illustration of the use of airplanes in geological exploration is seen in recent gold developments of Canada. Many of Canada's northern mining camps have hitherto been reached only by canoe in summer over long winding water courses with long portages, or by dog sled and pack train in winter over deep snows mid bitter cold. A few railroad lines now tap some of these distant fields like that of the Hudson Bay Mine at Flin Flon but as a rule the more inaccessible regions must await the coming of airplane service. The plane saves time and money, making places quickly accessible which, a few years ago, could not have been examined by geologists in less than two months. Four regular airplane companies operate in the mining districts of Canada. The statistics of one of these, the Canadian Airways Ltd. for the year 1935 indicate the magnitude of this air transport. The manager of this corporation at Winnipeg in a private communication of Jan. 18, 1936 states:

"We are still waiting a few statistics from our farthest north posts, but the following round figures will be close enough for comparison: Hours flown, 17,000; Miles flown, 1,600,000; Express, 5,250,000 pounds; Mail pounds, 700,000; and passengers, 14,000." He might have added what is more significant, *without the loss of a single life.*

What the airplane means in case of mine accidents is shown by the following case: A machinist at God's Lake was struck in the eye by a flying splinter of steel which lodged 1¼ inches behind the eyeball. The mine doctor, A. E. McGregor, at God's Lake decided the delicacy of the operation required the cooperation of an eye specialist. He radiophoned over Wings Ltd. system to a Winnipeg oculist. The two doctors discussed the case for 35 minutes, the Winnipeg specialist outlining the surgical method to be pursued. As ice was forming at God's Lake it was impossible to take the man out by airplane so the operation had to be performed at the mine. The radio was thus instrumental in a successful surgical operation which had been discussed over 400 miles of unbroken wilderness: the old and the new sciences were joined to bring relief to human suffering.

The airplane freight carried over Canadian territory in 1934 exceeded 7,220 tons and this tonnage has been steadily increasing.

Those of us who live today on the borderland of this Canadian land of snow in winter and open ground with its beautiful lakes in summer and fir-clad rocks should realize what a change has come with the ability to visit any section of this region in a few hours by air.

For centuries this storm-swept area has been almost uninhabited. Only a few Esquimaux, nomadic Indians of the Cree and Alaska tribes have maintained themselves by heroic struggle in this land of midnight sun in summer and of nearly total darkness in winter. Fur traders visited the land and dragged out their trapping wares by dog sled where last year one airplane company brought out 50,000 pounds of furs from the sub-Arctic plains in a day. Fishermen floated their birch canoes with limited catches of wonderful large fresh trout which today, by special cars from Ontario, reach Chicago in one day. Think of the potential value of the airplane which in 1935 carried from lakes of western Ontario 187,000 pounds of fresh fish which were moved so quickly that they did not have to be frozen for market.

Recent discoveries of rich ores of gold and other metals, especially radium, cobalt* and copper have brought into Canada the prospector and geological engineer to exploit the ores hidden under winter snow but exposed for three summer months when the sun shines steadily for almost 20 hours daily. Ten years ago this inaccessibility would have prevented extensive mining exploration under handicaps of low temperature and absence of roadways. May we illustrate by personal experience how airplanes are conquering this "frozen North"? In the summer of 1934 we were called to this snowland 400 miles northeast of Winnipeg to examine gold veins on Elk Island in God's Lake. My colleague told me that it was God's Lake because no one else would have it. Since a group of mining men have spent almost one million dollars in two years in opening a gold mine on this island it is evident that some men want portions of God's Lake quite badly.

This trip to north Manitoba to within 150 miles of Hudson Bay was my first experience in the air. We found our plane on the bank of Red River at Winnipeg loading gasoline and took off at 3:30 P.M. In four hours this huge plane skittered along the narrow open water of God's Lake 400 miles above Winnipeg.

* In 17 flying days one airplane brought 71 tons of cobalt ore to the railroad.

While the plane was soaring northward at 100 miles an hour one mile above dark green forests, streams, and lake-dotted plains, I could not help contrasting this geological trip with that of my first one on a bicycle forty years ago. Then I covered about 25 miles a day when mapping the New Jersey Greensands. Many years later in the Mexican Sierras we rode horseback twenty miles *daily,* but here we were in June, 1934 floating above the earth at the rate of over 1,000 miles a day and actually covering 400 in four hours. No wonder pronounced and exposed veins of mineralized rocks cannot escape the eagle eye of the geologist when he can look down from the sky and, spanning immense distances, watch the great massive granites cut by porphyry dikes and volcanic lavas and thus spot veins and contacts which may be rich in gold or other metal. Our return trip a week later was even more thrilling for we flew through great storm clouds and in sheets of rain forcing us 6,000 feet in altitude where we could look down on the cumuli billows 3000 feet beneath us. When they broke and formed again like waves of the sea we caught a glimpse of lake and forest which helped our pilot* gain location.

How accessible this remote region 130 miles east of the nearest railroad has become with two aviation lines and operating companies moving freight, mail, and passengers both winter and summer.**

Surely aviation has opened a new era for mining in remote corners of the earth. Already 52,000 square miles of Rhodesia have been surveyed and mapped from the air and much of Manitoba and Ontario is likewise mapped in detail. Island Lake with its 3,000 islands could not have been plotted in five years from the ground but we have examined the air maps of the lake which cover the entire region in greatest detail and these maps were made in a few days time.

*Aerial Surveying.*

Directly after the world war mapping wide regions from the air was under development. The progress of this important

* Mr. Herbert-Hollock Kenyon was the pilot for Lincoln Ellsworth in his recent flight and tragic rescue in January at Little America, Antarctic.

** Wings Ltd., a newcomer in Canadian aviation mine work, carried, from July to Aug. 1934, 892 tons and 7,738 mining men of whom we were included in last year's flying.

branch so essential for geological exploration is outlined in a late report of the Canadian Airways bulletin (The Bulletin, Canadian Airways Ltd., Feb. 1936) as follows:

"On a suitable day, 5000 feet altitude might be reached, with a good deal of effort, in anything from 60 to 90 minutes, and once established at that altitude, photography could be carried out at the rate of 60 miles an hour, provided there was no head wind. With the camera in use at the time, about thirteen minutes was required to change the film after each roll of 95 exposures was completed. With full tanks—about 75 square miles could be photographed in one flight."—Later 200 square miles were mapped in a day and with continued new inventions the speed and area mapped was greatly extended until today it is possible to cruise 120 miles an hour at an altitude of 18,000 feet and take photographs for seven hours.

In north Quebec two years ago a yoke of oxen were carried into the Chibougamou mining camp for hauling logs in the forest. As each weighed about 1400 pounds they were taken separately but it indicates that planes can now lift and ship freight of any description. Probably the record for this is that of the Bulolo Company where the plane in New Guinea flew from the coast over the mountains to a gold mine carrying a dredge tumbler shaft weighing three and one-half tons. (7,000 pounds.) Although this shaft was twelve feet long and eighteen inches in diameter it was raised and transported safely over the jungles to the mine. Through modern aviation mining camps in all parts of the world are visited by geologists and in record time. Only last year (1935) a New York engineer covered 25,000 miles by plane and visited all great continents in his travels.

The utilization of airplanes in geologic and topographic surveying has been rapidly expanding each year and the latest scheme is to take up geophysical prospecting from the air but we do not believe that this can reach as important scientific application as can the map work and outline of geological structures and rock formations.

In the summer of 1935 we covered 900 miles by plane on a trip to Knee, God's, and Island Lakes, Manitoba and completed a number of gold vein samplings in ten days which would have taken all summer to visit by canoe or dog team methods. If we wanted to inspect an outcrop 30 miles from some landing station we had simply to point out to our pilot the island or shore of the lake we wanted to study and he would fly over the place, taxi down carefully to watch for hidden rocks in the water, and finding a safe open spot would drop to the water and taxi to the shore. Such remarkable achievements were new experiences to me and indicate how much we owe to engineers capable of fitting a plane with floats for summer and skis for winter landing and barring the break-up season on the lakes, these planes maintain a regular schedule throughout the entire year.

## PART III

*Physical (Dynamic) Geology.*

Let us examine a third phase of geologic science which investigates changes of the earth's surface and forces causing elevation and depression of continents, earthquake shocks, volcanic eruptions and those processes more destructive than beneficial to human life. To the English geologist, Sir Charles Lyell (1797-1875) we are indebted for the doctrine which teaches that the key to the past is the present. His predecessor, a fluent writer, James Playfair had already mentioned this uniformity theory and suggested that recent earth changes were similar to those of past eras.

It remained however, for Lyell to found the branch of Dynamic or Physical Geology through observation of natural phenomena which he had seen in wide foreign travel. Van Hoff in Germany had also written related ideas but Lyell was the best exponent of modern Stratigraphic and Dynamic Geology.

Lyell's *Principles of Geology* which passed through twelve editions is still a readable book worthy of a place in every geologic library. This celebrated geologist from observations in 1841 at Niagara Falls rightfully interpreted the gorge as due to river erosion in late geologic time. He pointed out that continued cutting into Lake Erie would gradually destroy this mighty cataract because of the gentle dip of the limestone under the bottom of the lake. What such careful observations mean is seen in our history of the Great Lakes. For fifty years geologists have known the upper portion of North America was formerly deeply buried beneath glacial ice which extended almost to the southern boundary of Illinois. Recent investigations of extinct lakes which arose when the glaciers melted reveal the fact that their former shore lines are no longer parallel to the shore lines of the Great Lakes of today. What is more surprising is the discovery that the several levels of these ancient lake waters are not level with datum planes in different stages of their history. What this means is that for many thousand years the St. Lawrence river basin has been tilting *differentially* and while the lower end of Lake Michigan is now sinking a few inches in a century former elevations show a difference of 170 feet between the extinct lakes Warren and Algonkian.

If, therefore, sinking continues, the drainage of our present Great Lakes in a not far distant epoch will again flow into the Mississippi and the Gulf just as it formerly did before advancing glaciers buried the country with crushing thick ice sheets. Man cannot alter this rise and fall but he can interfere with stream diversion and for a time control both stream and lake discharge as he is now doing in forming a new 70 mile lake in the world's deepest chasm at Boulder canyon.

Through Physical Geology we investigate volcanic and earthquake phenomena and investigate earth stresses which fold rock masses of enormous thickness into lofty mountain ranges or bury their margin beneath the water of restless oceans. Earthquakes cannot yet be predicted with certainty but geologists can determine where they are likely to occur and what regions will remain free from such destructive catastrophes. In areas where they do occur man can construct shock resisting buildings and thus prevent loss of life and property.

En route to Valparaiso we met an engineer going to Chile to construct reservoirs which it was hoped would be shock proof. The need for such engineering work is very great. In 1927 during the Chilean earthquake the dam of the Braden Copper Company at Sewell gave way and its millions of gallons of impounded water for the mill rushed down Rancagua gorge at the rate of fifteen miles in twenty minutes destroying every living thing in its path. If retaining walls can be so constructed that they will resist such shocks millions of dollars will be saved. This is an engineering problem and partly the work for the geological engineer to solve.

*Underground Water in Human Affairs.*

The development of artesian waters belongs to the field of Stratigraphic Geology and constitutes an important phase of human welfare and progress. The amount of water in the atmosphere, if condensed, would cover the earth five inches deep. The volume in the oceans exceeds 300 million cubic miles, but the water stored below the surface in unseen caverns, fissures, and porous rock spaces is not as accurately known. Although scientists who have studied the problem do not agree we can safely estimate the amount at 100 million cubic miles, one-third that of the ocean, and enough, if extracted, to cover the earth 100 feet deep.*

To comprehend the vast amount of water stored underground in sedimentary rocks let us take the Cambrian Sandstone of Wisconsin and adjacent states. (Minn., Iowa and Ill.) This formation rests upon impervious granite and metamorphic rocks and under Appleton is 400 feet thick. The geologist King** estimated from the porosity of this standstone that there was theoretically present in each 100 feet a layer of water from 10 to 38 feet deep. If we take the minimum average for this formation at 500 feet and assume a porosity of only ten per cent, the amount would equal an inland sea having a depth of fifty feet over the entire area underlain by this sandstone.

While in some localities water from this horizon is highly mineralized it is usually excellent for drinking and municipal purposes and it is utilized in scores of towns and cities through artesian wells, as at Madison.

Probably the record flowing artesian well for Wisconsin is that of Sturgeon Bay which was completed in the summer of 1935 and yields at least 1,500 gallons of excellent water a minute of a temperature of 48 degrees Fahr. This flow will save the city $6,000.00 a year in pumping expenses alone.

More than one-half the water supply for the 120 million inhabitants of the United States comes from underground sources. Out of 191 cities with a population exceeding 50,000 there are 76 taking their water supply from rivers, 28 use lakes

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* Slichter, C.S. Water Supply Paper, 67, 1902.

** King, F.H. Principles and Conditions of the Movements of Ground Water. 19th Ann. Report, U.S. Geol. Survey, Part II, 1899, p. 70.

or ponds, 40 have impounded reservoirs, 44 obtain their supply from artesian wells, and three take it from *flowing springs.** (San Antonio, Texas with a population of 231,542 is one of the largest of these and uses nine wells all flowing in great volume from a depth of around 800 feet.)

Development of municipal water supplies depends on many factors. Cities of great size could not obtain enough water from underground wells and water in many localities underlaid by igneous rocks is not present in commercial quantity. New York city uses 100 million gallons daily from wells but this is only a fraction required for thirteen million inhabitants clustered about this metropolis. In some regions underground water is so highly mineralized or saline that even cattle cannot drink it and wells in Australia one mile deep yield water so hot that it must be cooled before the stock can drink it. The development of subterranean water therefore is a complex problem which geologic engineers are attempting to solve.

What are the record artesian wells in the United States, which, pouring out millions of gallons daily, seem like modern miracles?

We believe that the record well for Massachusetts was completed in 1935 at Dalton, Massachusetts which threw a geyser-like volume five inches above a 12 inch pipe before commencing to break and the flow was estimated in excess of 2,000 gallons per minute. Sturgeon Bay already mentioned has perhaps the record well in Wisconsin, but the largest flowing well of the United States is in the Roswell basin of New Mexico where the Oasis Cotton Company well of 1931 threw a stream of water nearly fifty feet high and is rated at a daily capacity of 13,-285,000 gallons.

In closing this division of our subject of underground water we may digress a moment to consider a question often asked of geologists, "Can anyone locate water below the surface by the DIVINING ROD?" Belief in this method of using a forked stick of witch hazel or willow to locate wells is still widely accepted and many refuse to believe that such results as are obtained by "water witching" are due to luck for the idea is not far removed from clairvoyancy or other occult superstition.

* Meinzer, O.E. Large Springs in the United States, Water Supply Paper 557, 1927.

It would seem impossible to exhaust subterranean water by well developments when such remarkable volumes exist locked in stratified rocks of the earth's crust. Continued pumping however, lowers the water table underground and unless the supply is renewed from rainfall and surface seepage through rocks the supply becomes critical and may eventually cease to furnish commercial supplies. Expanding necessities of fresh water supplies throughout the nation require exhaustive study of geologists who can help discover and develop these natural resources which are so essential to human life. Knowledge of earth formations, rock structures, and potential water horizons are within the province of geologic engineering. Failure to understand these subterranean conditions may prove costly. For example, some years ago city engineers located a large municipal reservoir for Staunton in the Shenandoah Valley and built a dam and conservation basin to impound the surface streams flowing through the region. No sooner was this basin filled when the entire volume of water disappeared suddenly. This was due to some undiscovered subterranean channel in the underlying limestone and caverns where the water found its way. Geologists would have shown that this entire valley is underlain by such cavernous rock and that fissure openings were possible. They would have investigated the sub-structure to determine the character of the basin and devised a method to prevent its escape.

In conclusion we should not forget that great historical eras of human history have been closely related to utilization of metals, minerals, and the treasures extracted from the earth's crust. There was once a Stone Age, then the Bronze and Iron age epochs, and through all ages has run the utilization of gold and silver as precious metals both for money and for jewels. Even precious stones, never essential for human progress, save from the esthetic emotional aspect, because of their intrinsic beauty, will forever attend advancing civilization. Had none of these products been available how changed this old world would have been and how retarded all civilization and human progress.

We have outlined some phases of Geologic Science which have an intimate relation with human progress. No science, however, should be rated solely for its utilitarian value. There is a cultural aspect as well as economic one, though not as readily evaluated. We gain inspiration from life through a scientific study of the Natural World and of the Universe which surrounds us. The ancient built his imaginative sphere upon superstition and in awe worshiped the violent forces of nature, fire, wind, water, and the earthquake over which he had no control. Modern science is slowly conquering natural destructive forces and bending them to commercial use. Each year adds new discoveries in every branch of natural and physical science.

There is a satisfaction in knowledge resulting from scientific discovery which is unknown to the savage intellect. Consumation of scientific research through new experimentation has not yet been attained and it is fortunate for mankind that much remains for future study as we seek to reveal the hidden secrets of *Mother Earth.* With other great Physical Sciences Geology is contributing her share in human progress and world welfare.

*In Commemoration of the Bicentennial of the Birth of*

# CARL WILHELM SCHEELE

GEORGE URDANG

*Director of the American Institute of the History of Pharmacy, Madison, Wisconsin.*

Two hundred years ago, on December ninth or nineteenth 1742—the exact date is disputed—Carl Wilhelm Scheele was born. On the twenty-first of May 1786 he died. Between these dates lies one of the most decisive periods of political history as well as of scientific history. As to political history the idea of democracy grew, more or less violently, into the realm of reality. As to scientific history the esoteric discussion of the abstract was superseded by the democratic search for the concrete. Theories were not to be imposed upon the facts any more but to be derived from them. The deductive and the inductive methods of research had finally changed their roles during this period.

It was this general situation which made the work of Scheele especially important. Here was a man to whom speculation meant nothing and the discovery and honest presentation of facts everything; one of the rare empirics whose special kind of genius enables them to put the right questions to the right subjects and to obtain the most surprising results in the most simple way and with the most simple apparatus.

Nothing in the early life of Carl Wilhelm Scheele indicated his later greatness. He was born in the then Swedish City of Stralsund (Pommerania) as the seventh of the eleven children of the brewer and later broker Joachim Christian Scheele and Margaretha Eleanora nee Warnekros(s). Two years later his father became bankrupt. There was neither much time nor much money to be devoted to the education of the boy whose shy and reserved behavior did not betray special talents anyway.

At the age of fourteen Carl Wilhelm Scheele left the private school which he had attended for eight years and decided to become a pharmacist. This decision proved to be of the greatest benefit to himself, to pharmacy, to chemistry and finally to the world at large. In spite of the most alluring offers made to him in later years, Scheele remained with pharmacy all his life. All his investigations and discoveries were made in the Swedish pharmacies in which he worked first as an apprentice and then as a clerk and finally in his own pharmacy in the small Swedish town of Köping. It can be assumed that it was the example of his older brother Johann Martin, born on February 14, 1734 and died on January 15, 1754, that influenced the boy's decision. This seems the more likely as Carl Wilhelm became an apprentice to the same man to whom his deceased brother had been apprentice, i.e., to the apothecary Martin Andreas Bauch, the owner of the pharmacy at the Unicorn in Gothenburg.

Now the latent talents and energies of the young man began to develop. He found himself surrounded by substances the real nature of which was not or merely incompletely known and which he could investigate and experiment with as he pleased, pushed by no one and responsible only to himself. His master, recognizing the unusual zeal of his apprentice, not only encouraged Scheele's scientific curiosity in granting him the material needed and as much time as possible, but in addition put his well equipped library at his apprentice's disposal. It was especially the German apothecary Caspar Neumann's "Praelectiones Chemicae" and the "Cours de Chimie" of the French pharmacist Lemery which young Scheele made subject of an intensive study and which formed the basis of his early experiments. It was during the eight years of his stay in Gothenburg (1757 to 1765) and the following three years of clerkship at the Pharmacy at the Spotted Eagle at Malmö (1765 to 1768) owned by the apothecary Peter Magnus Kjellström that Scheele laid the groundwork for most of the discoveries which made him one of the greatest chemists of all time.

Anders Jahan Retzius, who became acquainted with Scheele at Malmö and was the first scientist to recognize—and to take advantage of—the genius in the young apothecary clerk, described his young friend in a letter written about twenty years later (1786) to Wilcke as follows:

"His (Scheele's) genius was given to him exclusively for physical science. He had absolutely no interest in any other. It is doubtless for this reason that his talents seemed to be poor if other matters were concerned. His memory was excellent. However, this too seemed only fitted to retain matters relating to chemistry. During his stay at Malmö he bought from Copenhagen as many books as his small pay enabled him to procure. These he read through once or twice. Then he remembered all that he desired to recall, and never again consulted the books. Without systematic training and with no inclination to generalize, he occupied himself mainly with experiments. From the time of his apprenticeship at Gothenburg he had worked several years without plan and for no other purpose than to note phenomena; these he could remember excellently. Eleven years' continuous exercise in the art of experimenting had enabled him to collect such a store of facts that few could compare with him in this respect. In addition he had gained a readiness in devising and executing experiments such as is rarely seen. He made all kinds of experiments, so to say, pell-mell. This taught him what many a doctrinaire could never learn: since working by no formulated principles he observed much and discovered much that the doctrinaire would consider impossible, in as much as it was opposed to his theories. I once persuaded him during his stay at Malmö to keep a journal of his experiments, and, on seeing it, I was amazed not only at the great number he made, but also at his extraordinary aptitude for the art."

A. E. Nordenskiöld in his book "Carl Wilhelm Scheele, Nachgelassene Briefe und Aufzeichnungen," Stockholm, 1892, in editing Scheele's "Laboratory Notes" made the following comment:

"These notes prove once more that the basic experiments for a large part of Scheele's great discoveries have already been made at Gothenburg and Malmö, that already the apprentice had subjected to an exact investigation the entire material offered to a chemist in a pharmacy of his time achieving results which, if published immediately, would have made the years 1767-1770 a turning point in the development of chemistry."

The statements of Retzius and Nordenskiöld, the one based on personal knowledge and the other on the laboratory notes of the great apothecary and the perspective given by a distance of more than a century, are highly illuminating. They prove that the fact of Scheele's being a pharmacist was by no means incidental and negligible or even regrettable and detrimental to his research work as some of Scheele's biographers intimate. On the contrary, it was of greatest importance for the kind as well as for the amount of his achievements. It may well be said that it was the good luck of Scheele and of chemistry that Scheele was, first and above all, a pharmacist. Here and only here a vast variety of subjects offered themselves to his scientific curiosity. Here and only here he was given the independence of work and conclusion which he needed. It was the *apothecary* Scheele who, encouraged by Torbern Bergman but carrying on his experiments quite independently, became interested in black magnesia which interest resulted in the recognition of the individuality of manganese and baryta and the discovery of chlorine. It was the *apothecary* to whom the problem of Prussian blue offered itself leading to several important results among them the preparation of hydrocyanic acid, and whose daily contact with tartar brought about the discovery of tartaric acid, the first of the chain of organic acids isolated by him. The red mercury oxide from which Scheele gained oxygen as early as in 1771-72 was a much used *pharmaceutical* substance and it was a typical *pharmaceutical* procedure, the preparation of lead-plaster, which lead Scheele to the observation and isolation of glycerin. It was the needs of *pharmacy* which caused Scheele to look for an inexpensive way of preparing phosphorus and for a more convenient and less dangerous method of preparing calomel.

Although pharmacy was undoubtedly the basis of Scheele's chemical work, his being a pharmacist did not prevent him from solving chemical problems not offered within the frame of his profession. Sweden is a land of mining. Her mountains contain valuable ores. Scheele refused to leave pharmacy for a position in industry. He did not go to the mountains, but the mountains came to him. In materials sent to him he discovered molybdic acid and tungstic acid and it was he who gave to industry the methods for the analytical separation of iron and manganese and for the decomposition of mineral silicates used for more than a century.

Until his early death at the age of only forty-three years

Scheele reported one discovery and observation after the other in such rapid succession that his contemporaries were almost overwhelmed. Thus Lorenz v. Crell, the renowned founder and editor of Crell's Chemische Annalen after having received the news about glycerin wrote to Scheele on December 2, 1783 as follows: "I am wondering what more will be disclosed by you! I dare to assume that no chemist is known to us who has ever made so many and so important findings. As soon as you have made another new discovery . . . please send it to me immediately without caring for postage. Your letters are not too expensive for me at any price."

This reverence paid Scheele by v. Crell was only one of the innumerable proofs of the high esteem in which the humble apothecary was held by his contemporaries. At the age of thirty-two, still being an apothecary clerk and not yet having passed the Swedish apothecary examination, Scheele was made a member of the Swedish Royal Academy of Science and thus given the highest scientific distinction Sweden had to offer. It was no less a person than the great Torbern Bergman who took pride in initiating the new member and to welcome Scheele as follows:

"For several years I was witness of your unrivalled industry, of your special talent to elicit the secrets of nature by purposefully arranged experiments, and of the ingenious conclusions that you have drawn. Hence what can be more natural than the particular joy with which a man like me, loving his science ardently, sees you take a place of honor to which your merit and nothing else has paved the way for you."

After the death of Bergman, J. C. Wilcke, then Secretary of the Swedish Royal Academy of Science, wrote in a letter to Scheele under the date of August 9, 1784 as follows: "Since we lost Bergman, it is you in whom we put the greatest confidence that you will keep up our (Sweden's and the Academy's) reputation as to chemistry."

The authority which Scheele enjoyed was so great, and his honesty and simplicity of character so obvious and disarming that none of the usual scientific jealousies and quarrels ever touched him. When his book on air and fire, due to the negligence of his publisher, appeared so late that some of his statements concerning oxygen were in the meantime made and published by other authors, nobody dared to raise the question of plagiarism.

Naturally, the question as to the priority of the discovery of oxygen has been discussed again and again. It was not until 1892 that the publication of Scheele's correspondence and laboratory notes, presented to the world by the Swedish arctic explorer A. E. Nordenskiöld definitely proved that prior to 1773, that is at least a year before the date of Priestley's discovery, Scheele had prepared oxygen from the carbonates of silver and mercury, from mercuric oxide, nitre and magnesium nitrate, and by the distillation of a mixture of manganese oxide and arsenic acid.

According to Rosenthaler (Ber. Deutsch. Pharm. Ges. 1904) it was Scheele who for the first time consciously showed that it is possible and necessary to prepare systematically the plant-constituents as chemical individuals and that, for this reason, "Scheele and nobody else has to be regarded as the founder of modern plantchemistry." Since Scheele in 1783 prepared hydrocyanic acid from coal, ammonium chloride and potash, Ferchl-Süssenguth in their "Kurzgeschichte der Chemie," Mittenwald, 1936, give to him and not to Wöhler the credit to have been the first to perform an organic synthesis. Scheele employed and in 1782 recommended sterilization, and his observation that different parts of the solar spectrum influence the decomposition of silver chloride in very different degrees (1775) has been considered the beginning of spectral photography.

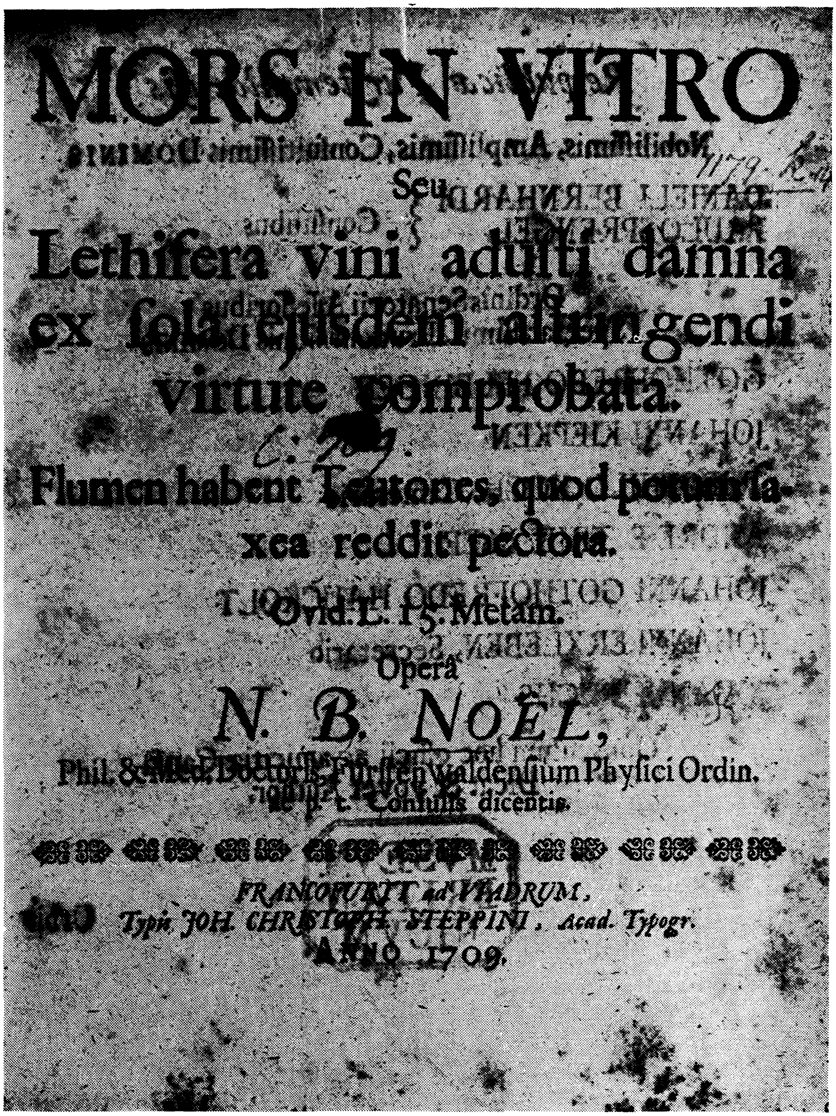
Scheele was so exclusively devoted to his science on the one hand and to his pharmaceutical service to his fellow citizen on the other that he literally had no private life. In his entire correspondence there is, besides not very frequent letters to his parents and brothers, hardly one note which is not devoted or does not refer to his work. There was never a woman in his life. The widow of the preceding owner of the pharmacy at Köping took care of his household for ten years. He married her three days before his death in order to secure for her the inheritance of his small fortune.

The profit drawn by a peaceful world from the discoveries of C. W. Scheele has been enormous. The work of this "corner druggist" has become a corner stone in the edifice of modern civilization. The bleaching and the laundry industry and wide fields of chemical disinfection among them that of water purification are inconceivable without chlorine. The fruit acids discovered by Scheele are of highest importance for the modern foodstuff and beverage industries. Tungsten and molybdenum, to the discovery of which Scheele paved the way, are indispensable in modern steel industry, and glycerin, finally, belongs to our daily life commodities used for a multitude of purposes and in many industries.

In 1930 the Association of American Soap and Glycerin Producers sent to the Swedish Crown Prince a message felicitating him on the discovery of glycerin by a Swedish citizen. Today it would be up to the manufacturers of explosives using nitroglycerin as the basis of their deadly products to do the same.

In 1892 the committee for the erection of a Scheele monument at Stockholm stated in a public pronouncement that "Scheele contributed more to the development of the era in which we are living than diplomatic negotiations and pitched battles."

At the present time, fifty years later, we are once more in the midst of pitched battles. However, honoring nevertheless the memory of the great men of science and peaceful progress, the memory of men like Scheele, we are reminding ourselves and the world of what we are fighting for.



# MORS IN VITRO

Seu

**Lethifera vini adulti damna ex sola ejusdem adurengendi virtute comprobata.**

Flumen habent Teutones, quod potum saxea reddit pectora.

Ovid. L. 15. Metam.

Opera

*N. B. NOEL,*

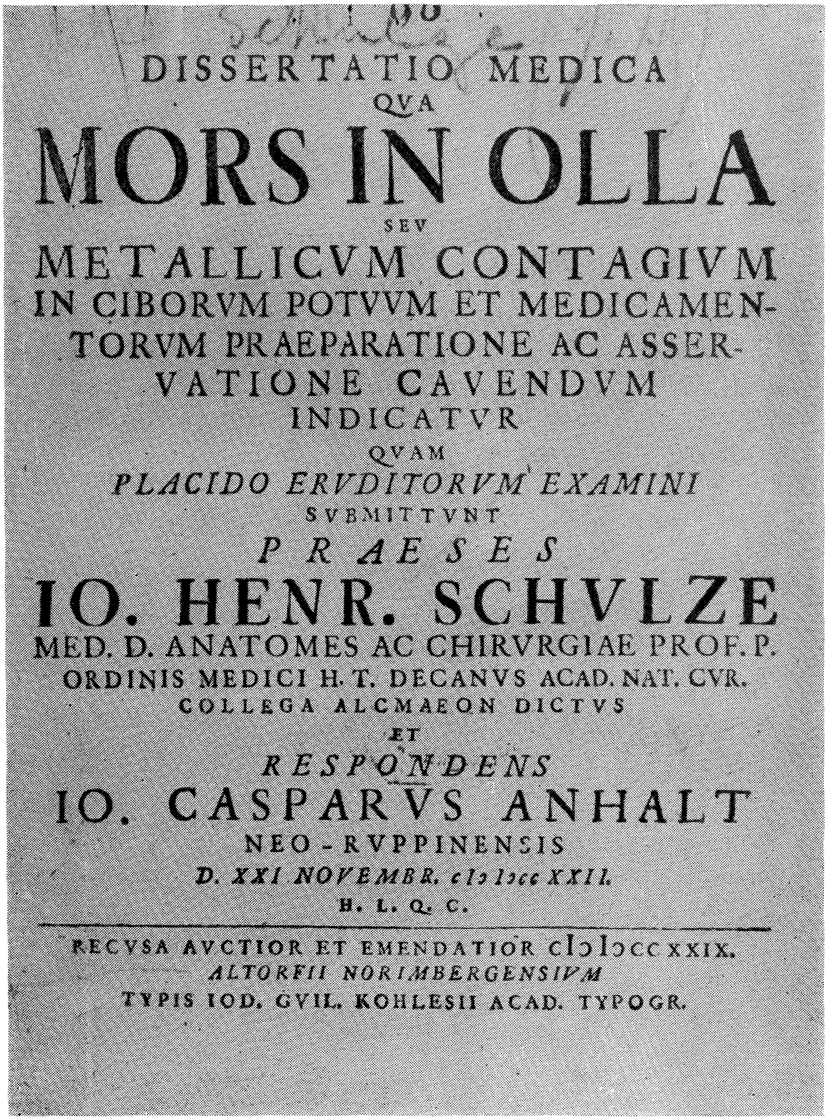
Phil. & Med. Doctoris, Fürstenwaldensium Physici Ordin. ac p. t. Consulis dicentis.

*FRANCOFURTI ad VIADRUM,*

*Typis JOH. CHRISTOPHI STEPPINI, Acad. Typogr.*

ANNO 1709.

Title page of Mors in Vitro (Death in the Glass or the Deadly Evils of Spirituous Liquors). 1709.



DISSERTATIO MEDICA
QVA
MORS IN OLLA
SEV
METALLICVM CONTAGIVM
IN CIBORVM POTVVM ET MEDICAMENTORVM PRAEPARATIONE AC ASSERVATIONE CAVENDVM
INDICATVR
QVAM
*PLACIDO ERVDITORVM EXAMINI*
SVBMITTVNT
*PRAESES*
IO. HENR. SCHVLZE
MED. D. ANATOMES AC CHIRVRGIAE PROF. P.
ORDINIS MEDICI H. T. DECANVS ACAD. NAT. CVR.
COLLEGA ALCMAEON DICTVS
ET
*RESPONDENS*
IO. CASPARVS ANHALT
NEO-RVPPINENSIS
*D. XXI NOVEMBR. cIↃ IↃcc XXII.*
H. L. Q. C.

RECVSA AVCTIOR ET EMENDATIOR cIↃIↃCCXXIX.
*ALTORFII NORIMBERGENSIVM*
TYPIS IOD. GVIL. KOHLESII ACAD. TYPOGR.

Title page of Mors in Olla (Death in the Pot or Metallic Poisons in Foods, Beverages and Drugs). 1722.

# DEATH IN THE POT

H. A. SCHUETTE

*Department of Chemistry, University of Wisconsin*

"Death in the pot" is a Biblical phrase (II Kings 4:40) which began to appear soon after the turn of the eighteenth century—and perhaps earlier although the record is not clear on this point—as title or subtitle of medical treatises and books on the subject of food contamination by metallic containers, the misuse of alcoholic beverages and the deliberate, wilful adulteration of foods, a practice which was once euphemistically called "a legitimate form of competion."

Heading the list is a medical treatise in Latin, Mors in Vitro, which appeared in 1709 under the authorship of N. B. Noel, of whose life and activities no more is known than that which can be gleaned from the title page of this little brochure of some seventeen pages. The subtitle reveals the substance of this dissertation in which the author develops the thesis that brandy and similar alcoholic beverages exert an astringent action upon the organs of digestion and assimilation.

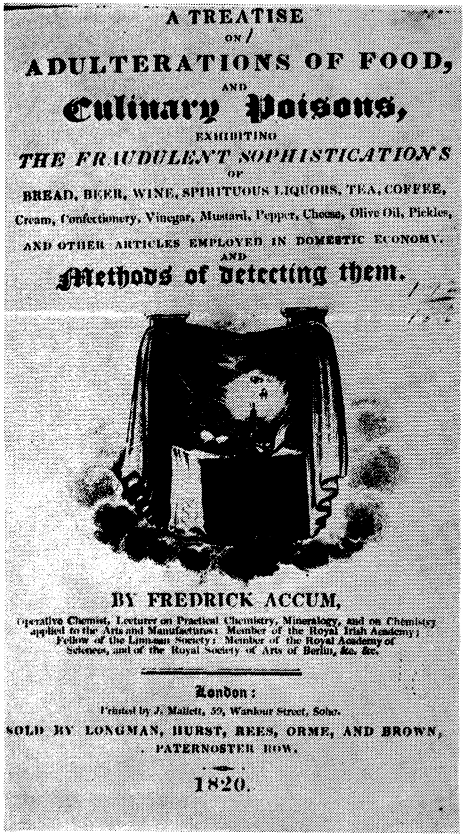
Fitting perhaps better into the picture than the preceding title is that of another medical treatise, Mors in Olla, written by John Henry Schulze in 1722. It is a pamphlet of thirty-two pages in which the author warns against the practice of preparing or storing foods in containers made of copper, brass, tin or lead. He discusses, also, the probable deleterious effects on the human organism of bismuth, antimony, arsenic and zinc when food or drink is brought in contact with them at certain temperatures. He who may be tracing the history of rickets will find herein the illuminating information that this "native English disease may, perhaps, be not unjustly attributed to poisons from tin which are transferred to edibles, and from these a slow and malignant poison gradually accumulates in the body."

The author of this publication was a physician and philosopher who studied medicine in the University of Halle from which he received his degree in 1717. Professor of medicine for a while, he eventually turned to theology and history. It is as an historian of medicine that he made his mark.

The scene shifts now from Germany to England; the time less than one hundred years later. In 1793 there appeared in London a young man of Teutonic ancestry, Friedrich Christian Accum, who obtained work as an assistant in the laboratory of the Brande pharmacy. His profession, as officially recorded, was that of chemist. He improved his time by attending chemical lectures in London, made the acquaintance of some eminent scientists there and came under the tutelage and influence of William Nicholson, a versatile chemist, author of books on chemistry and founder of the *Journal of Natural Philosophy, Chemistry and the Arts*. He became a useful assistant to Nicholson who, apparently, was not unappreciative of the services rendered by his young associate. Under the anglicized name of Frederick Accum he became a frequent contributor to Nicholson's *Journal*, first on subjects of general chemical interest and then on the more specialized one of adulterations. In this subject he was later to rank as the foremost chemist of his time.

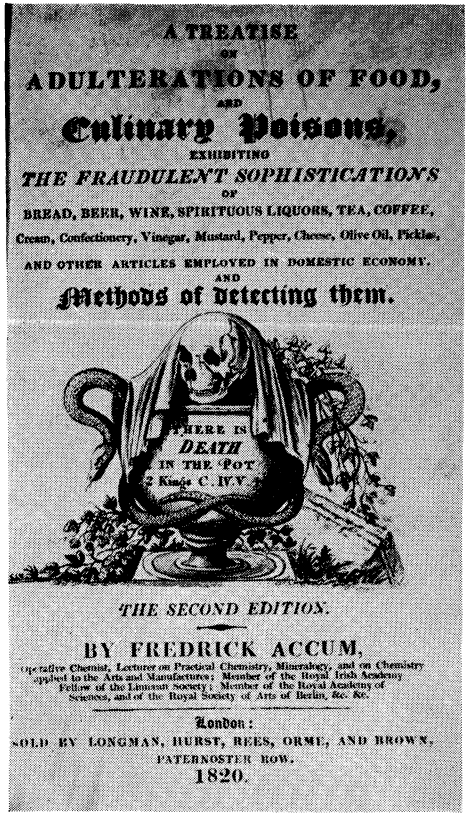
In as much as the immediate purpose of this communication is not to present a detailed account of the life while in England of this man of "reckless zeal and industry"—Browne has already intimately described the career of this most interesting chemical character in the *Journal of Chemical Education* (1925)—it may suffice to state that in the twenty-year period which began for him in 1800 he was a merchant in chemists' supplies, "operative chemist," lecturer, teacher and popularizer of chemistry who "blended chemical science with rational amusement." Pioneer crusader against the then rather common practice of adulterating food, author of some twenty books, industrial chemist and early investigator of municipal gas-lighting systems, analytical, consulting and technical chemist, he became one of the best known men in London.

The most widely celebrated of all his publications is the one entitled Treatise on the Adulterations of Food and Culinary Poisons. It appeared early in the year 1820 and now, in retrospect, is deemed to be a classic in that it represents the first serious effort to cope with the difficult problems of food adulter-


A TREATISE
ON
ADULTERATIONS OF FOOD,
AND
Culinary Poisons,
EXHIBITING
*THE FRAUDULENT SOPHISTICATIONS*
OF
BREAD, BEER, WINE, SPIRITUOUS LIQUORS, TEA, COFFEE,
Cream, Confectionery, Vinegar, Mustard, Pepper, Cheese, Olive Oil, Pickles,
AND OTHER ARTICLES EMPLOYED IN DOMESTIC ECONOMY.
AND
Methods of detecting them.

BY FREDRICK ACCUM,
Operative Chemist, Lecturer on Practical Chemistry, Mineralogy, and on Chemistry applied to the Arts and Manufactures; Member of the Royal Irish Academy; Fellow of the Linnæan Society; Member of the Royal Academy of Sciences, and of the Royal Society of Arts of Berlin, &c. &c.

London:
Printed by J. Mallett, 59, Wardour Street, Soho.
SOLD BY LONGMAN, HURST, REES, ORME, AND BROWN,
PATERNOSTER ROW.
1820.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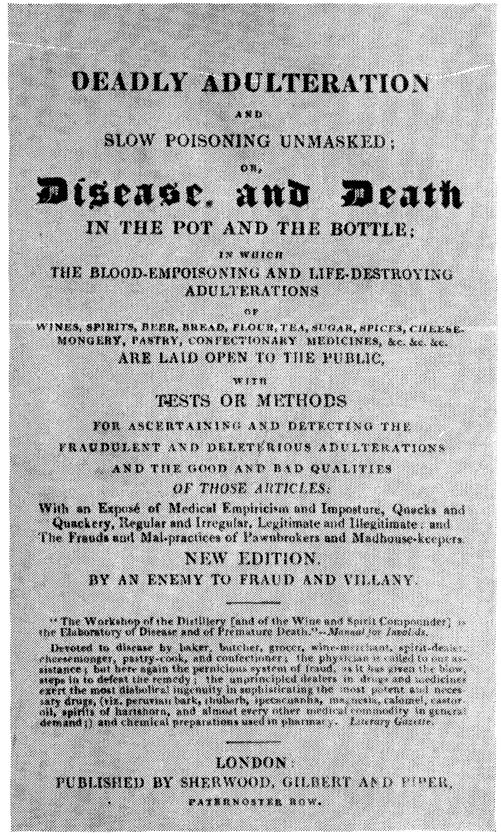
DEADLY ADULTERATION
AND
SLOW POISONING UNMASKED;
OR,
Disease and Death
IN THE POT AND THE BOTTLE;
IN WHICH
THE BLOOD-EMPOISONING AND LIFE-DESTROYING
ADULTERATIONS
OF
WINES, SPIRITS, BEER, BREAD, FLOUR, TEA, SUGAR, SPICES, CHEESE-MONGERY, PASTRY, CONFECTIONARY MEDICINES, &c. &c. &c.
ARE LAID OPEN TO THE PUBLIC,
WITH
TESTS OR METHODS
FOR ASCERTAINING AND DETECTING THE
FRAUDULENT AND DELETERIOUS ADULTERATIONS
AND THE GOOD AND BAD QUALITIES
*OF THOSE ARTICLES:*
With an Exposé of Medical Empiricism and Imposture, Quacks and Quackery, Regular and Irregular, Legitimate and Illegitimate: and The Frauds and Mal-practices of Pawnbrokers and Madhouse-keepers.
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Devoted to disease by baker, butcher, grocer, wine-merchant, spirit-dealer, cheesemonger, pastry-cook, and confectioner; the physician is called to our assistance; but here again the pernicious system of fraud, as it has given the blow, steps in to defeat the remedy; the unprincipled dealers in drugs and medicines exert the most diabolical ingenuity in sophisticating the most potent and necessary drugs, (viz. peruvian bark, rhubarb, ipecacuanha, magnesia, calomel, castor-oil, spirits of hartshorn, and almost every other medical commodity in general demand;) and chemical preparations used in pharmacy.—*Literary Gazette.*

LONDON:
PUBLISHED BY SHERWOOD, GILBERT AND PIPER,
PATERNOSTER ROW.

Title pages of treatises on food adulteration.

ation. Writers have inaccurately referred to this book as "Death in the Pot" but, if they have erred, it is not without reason because Accum embellished the cover with skull and cross-bones on a pall with this scriptural text beneath it and in the second edition of this work he states,

"The design of the Treatise will be fully answered, if the views here given should induce a single reader to pursue the object for which it is published; or if it should tend to impress on the mind of the Public the magnitude of an evil, which, in many cases, prevails to an extent so alarming, that we may exclaim, with the sons of the Prophet, 'There is death in the pot'."

The demands of the public for this pioneer work within the next three years were not satisfied until four editions had been printed. Its popularity extended even beyond the British Isles for translation into several foreign languages followed its appearance and a Philadelphia publisher made it available for American readers by bringing out a reprint edition.

The extensive reviews which were given Accum's book by the periodicals of his day not only reflect the public temper on the exposure of the practices which it contains but also reveal the various impressions which it created over a century ago. A few excerpts from some of these reviews will suffice to illustrate the situation and to describe the book and its contents.

The *London Literary Gazette*,[1] reviewing the book in advance of presentation to the public commented as follows:

"As we may safely prognosticate that this volume will soon be as widely diffused as its curious and vitally important character merits, we seize the earliest opportunity of making it known to our readers, since in a very few weeks the original would supersede, in every hand, our claim to novelty. We have heard at various times of this and that fraud, in the substitution of spurious and often deleterious articles for the necessaries of life; but never could we conceive so frightful a picture of imposition and villainy as thus bringing the poisonous ingredients into one point of view presents (*sic*). One has laughed at the whimsical description of these cheats in Humphrey Clinker, but it is really impossible to laugh at Mr. Accum's exposition. It is too serious for a joke to see that in almost every thing

[1] Jan. 15, 1820, No. 156, pp. 32-38.

which we eat or drink, we are condemned to swallow swindling, if not poison—that all the items of metropolitan, and many of country consumption, are deteriorated, deprived of nutrious properties, or rendered obnoxious to humanity, by the vile arts and merciless sophistications of their sellers. So general seems the corruption, and so fatal the tendency, of most of the corrupting materials, that we can no longer wonder at the prevalence of painful disorders, and the briefness of existence (on an average) in spite of the great increase of medical knowledge, and the amazing improvement in the healing science, which distinguish our era. No skill can prevent the effect of daily poisoning; and no man can prolong his life beyond a short standard, where every meal ought to have its counteracting medicine. Had Shakespeare written now, in London, he surely would have altered the exclamation of Jacques,[2]—

'As I do *live* by food I met a fool';

for to be germane to the matter, he should say:—

'As I do *die* by food, I met a fool.'

"In short, Mr. Accum acts the part of Dionysius with us; only the horse hair by which he suspends the sword over our heads allows the point gradually to enter the flesh, and we do not escape, like Damocles, with the simple fright: yet it is but justice to acknowledge, that in almost every case he furnishes us with tests whereby we can ascertain the nature of our danger, and no man could do more towards enabling us to mitigate or escape from it.

"Advising our readers to abstain from perusing the annexed synopsis till they have dined, that they may have one more meal in comfort ere they die, we proceed to the various heads under which the author ranges his dread array."

After describing at some length the practices of the adulterator as revealed by Accum, the reviewer continues:

"It is so horribly pleasant to reflect how we are in this way be-swindled, be-trayed, be-drugged, and be-devilled, that we are almost angry with Mr. Accum for the great service he has done the community by opening our eyes, at the risk of shutting our mouths for ever.

[2] As You Like It, Act II, sc. vii, 1. 13.

"His account of water is so fearful, that we see there is no wisdom in the well; and if we then fly to wine, we find from his analysis, that there is no truth in that liquid; bread turns out to be a crutch to help us onward to the grave, instead of the staff of life; in porter there is no support, in cordials no consolation; in almost every thing poison and in scarcely any medicine cure."

This lugubrious note is followed by an extensive list of particular cases, after which the reviewer brings the whole to a quick conclusion thus:

"As we read on we learn the method of manufacturing adulterated vinegar, adulterated cream, adulterated lozenges, adulterated mustard, adulterated lemon acid, poisonous Cayenne, poisonous pickles, poisonous confectionery, poisonous catsup, poisonous custards, poisonous anchovy sauce, poisonous olive oil, poisonous soda water; and, if not done to our hands, of rendering poisonous all sorts of food by the use of copper and leaden vessels. Suffice it to record that our pickles are made green by copper; our vinegar rendered sharp by sulphuric acid; our cream composed of rice powder or arrow root in bad milk; our comfits mixed of sugar, starch, and clay, and coloured with preparations of copper and lead; our catsup often formed of the dregs of distilled vinegar with a decoction of the outer green husk of the walnut, and seasoned with all-spice, Cayenne, pimento, onions, and common salt—or if founded on mushrooms, done with those in a putrefactive state remaining unsold at market; our mustard a compound of mustard, wheaten flour, Cayenne, bay salt, radish seed, turmeric, and pease flour; and our citric acid, our lemonade, and our punch, to refresh or to exhilerate, usually cheap tartareous acid modified for the occasion."

Finally, as an added word of commendation and approval of Accum's book, the review states, "his work, besides, contains many curious documents and useful recipes; and it is replete with intelligence, and often guides to the right while it exposes the wrong. . . . We never met a publication more likely to be deservedly and universally popular."

*Blackwood's Edinburgh Magazine*[3] found something amus-

[3] Vol. 6, pp. 542-554, 1820.

"We bless our stars that a knowledge of the art of cookery does not constitute any part of our requirements. We are so thoroughly convinced *a priori* of the disgusting characters of its secrets, and the impurity of its details, that we are quite sure a more intimate acquaintance with them would have embittered our existence, and have destroyed for ever the usual healthy tone of our stomach. We make it a point, therefore, uniformly, to lull our suspicions, and to discuss any savoury dish that may be placed before us, without asking any questions about its ingredients. It is really much more agreeable to be allowed quietly to mistake a stewed cat for a rabbit, than to be made *post factum,* accessaries to the deception. When we have finished our salad, we are by no means anxious to receive any proof, however clear, that it was seasoned with a preparation of Whale's blubber instead of Florence oil. And we should consider ourselves under a very trifling obligation to any 'damned good natured friend' who should take the trouble of demonstrating that the Reindeer tongue, which gives so pleasant a relish to our breakfast, had been recently abstracted from the jaws of some distempered poodle. Misfortunes of this kind, it is impossible for human sagacity to prevent, while they are perhaps too grievous for human patience to bear. Our best refuge, therefore, is our ignorance, and where that alone constitutes our happiness, surely we must agree with the poet, that it is folly to be wise.

"Mr. Accum, it appears, is one of those very good-natured friends above aluded to, who is quite resolved not to allow us to be cheated and poisoned as our fathers were before us, and our children will be after us, without cackling to us of our danger, and opening our eyes to abysses of fraud and imposition, of the very existence of which we had until now the good fortune to be entirely ignorant. His book is a perfect death's head, a *memento mori,* the perusal of any single chapter of which is enough to throw any man into the blue devils for a fortnight. . . . Mr Accum puts us something in mind of an officious blockhead, who, instead of comforting his dying friend, is continually jogging him on the elbow, with such cheering assurances as the following, 'I am sorry there is no hope; my dear fellow, you must kick the bucket soon. Your liver is diseased, your lungs gone, your bowels as impenetrable as marble, your legs swelled like door posts, your face as yellow as a guinea, and the doctor just now assured me you could not live a week.' It is quite in vain for Mr Accum to allege that 'our bane and antidote are both before us'; that he has not only made us acquainted with the deadly frauds which are daily practiced on our stomachs, but afforded us unerring chemical tests by which these frauds may be detected. Is it for a moment to be supposed, that we are not to eat a muffin or a slice of toast without first subjecting it to an experiment with muriate of barytes? Does Mr Accum expect us to resort to the Cyder cellar, or the Burton ale house, loaded with retorts and crucibles, and with our pockets crammed with tincture of gall, ammonia, and prussiate of potash? Are we to refuse to partake of a bottle of old Madeira, whenever we may chance to have forgotten to provide ourselves with the necessary solution of subacetate of lead? For our own part, we must say, that rather than to submit to such intolerable restrictions as these, we should prefer (dreadful alternative!) to double the dose of poison, and put a speedy end to our existence, by devouring a second roll to breakfast, and swallowing twice as much win and porter after dinner as we have hitherto been accustomed to.

"Melancholy as the details are, there is something almost ludicrous, we think, in the very extent to which the deceptions are carried. So inextricably are we all immersed in this mighty labyrinth of fraud that even the vendors of poison themselves are forced, by a sort of retributive justice, to swallow it in their turn. Thus the apothecary, who sells the poisonous ingredients to the brewer, chuckles over his roguery and swallows his own drugs in his daily copious exhibitions of brown stout. The brewer, in his turn, is poisoned by the baker, the wine-merchant, and the grocer. And, whenever the baker's stomach fails him, he meets his *coup de grace* in the adulterated drugs of his friend the apothecary, whose health he has been gradually contributing to undermine, by feeding him every morning on chalk and alum, in the shape of hot rolls."

After citing cases from the book, the writer concludes:

"The very mention of these things has thrown our whole frame into disorder. Even if it could be established that death was in the bottle as well as the pot, we should pitch Mr Accum to the devil and swallow the delicious poison at the rate of three bottles per diem, till the exhaustion of our cellar or our constitution should unwillingly force us to desist."

With less levity the *British Review and London Critical Journal*[4] commented:

"Mr. Accum seems determined that even the outside of his book shall awaken our fears. The cover of our copy bears a death's head emblazoned upon a pall and, underneath, the motto 'There is death in the pot.' The pall is supported by the point of a dart. Four other darts support the four corners of the device. Twelve serpents, with forked tongues and tails entwined, form a terrific wreath around; while the middle is occupied with a large cobweb, delineated with much attention to detail, in the center of which a spider, full as large as a moderate sized hazel nut, and so frightful that more than one young lady of our acquaintance would think it necessary to scream at the sight of it, holds in its envenomed fangs an ill-fated fly, which is sinking under the loss of blood and buzzing in the agonies of death.

"We are by no means desirous to raise or maintain a popular clamour; but Mr. Accum certainly advances some weighty charges, and his work comes with an advantage in bearing a name not unknown to the scientific world. Of the adulterations specified, some are deleterious, and others merely fraudulent. It appears from the dedication, that the work originated in a suggestion of his grace the Duke of Northumberland, while cultivating the study of experimental chemistry in Mr. Accum's laboratory.

"Quotations from Mr. Accum's book have appeared in the public prints; indeed a great part of the work itself is drawn from previous documents. But until the knowledge of the evil leads to some effectual efforts for its removal, we do not think that because much of the information which he thus affords is old, it therefore is not to be repeated."

After offering the readers generous samples of the contents of the book "both from the original matter of Mr. Accum, and from his citations drawn from previous authors," the review then proceeds to a close with the following note of appreciation in which is contained, also, a prophecy which came true.

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[4] Vol. 15, pp. 170-191, 1820.

"To Mr. Accum we are of opinion that the public are unquestionably under an obligation. He has brought forward a subject in a popular form, to which general attention ought constantly to be directed, as long as the evil continues to exist. We certainly like the inside of his book better than the outside; which, however, is more than we can say of many books that come before us; of course he will be exposed to obloquy: this he must expect. Much ill-will he has, no doubt, to experience from that description of persons, whose instinctive dread of change makes them hate to be told that anything is wrong, and ought to be set right: and whose rage increases tenfold if a clear case is made out. But far greater will be the rage of those whose delinquency he has exposed, and who, when they have read whatever is most severe in his representations, look into themselves, and there view the original from which the picture is taken. . . ."

It concludes with the following reflection:

"How melancholy a view does it afford of human nature, when we see tradesmen, who have long passed for respectable, convicted, in our courts of justice, of gaining a livelihood by fraud; and by adulterations, some of them injurious to the constitution, and gradually destructive of life; when we find them easy and practised in these crimes, depending on them as a regular mode of making a fortune by business, and shameless when exposed! What resentment would one of these honest dealers express, if his minister spoke to him, from the pulpit, of the depravity of the human heart! These are the people who cry out and affect to be shocked, at what they call the odious and degrading doctrine: that doctrine of the deep deceit and desperate wickedness of our unrenewed nature, which therefore offends us, because it shows us to ourselves. These are the sort of gentry who begin to swell and to give themselves all the airs of honest men when they hear reflections of this kind; as the suspected thief swaggers and threatens with your purse in his pocket. 'Tis hard they say, that they should wrong no man, and labour (poor innocent souls!) to earn an honest livelihood;—and then, if they can find time to step out of church of a Sunday, after minding their business all the week, to be talked to in such a way! Aye, and what is worse, if they arrive there in time, they must either not join in the service, or else be content to call themselves 'miserable sinners!'—This is really too much, for a man self-approved, and unconscious of any bad motives or intentions, to take patiently."

The *Edinburgh Review*[5] also found, in the appearance of this book, a text for a stinging comment upon the times:

"It is curious to see how vice varies its forms, and maintains its subtance, in all conditions of society;—and how certainly those changes, or improvements as we call them, which diminish one class of offences, aggravate or give birth to another. —In rude and simple communities, most crimes take the shape of Violence and Outrage—in polished and refined ones of Fraud. Men sin from their animal propensities in the first case, and from their intellectual depravation in the second. The one state of things is prolific of murders, batteries, rapines and burnings —the other of forgeries, swindlings, deformations, and seductions. The sum of evil is probably pretty much the same in both—though probably greatest in the civilized and enlightened stage; the sharpening of the intellect, and the spread of knowledge, giving prodigious force and activity to all criminal propensities.

"Among the offences which are peculiar to a refined and enlightened society, and owe their birth, indeed, to its science and refinement, are those skillful and dexterous adulterations of manifold objects of its luxurious consumption, to which their value and variety, and the delicacy of their preparation, hold out so many temptations. While the very skill and knowledge which are requisite in their formation, furnish such facilities for their sophistication."

The review closes with a note of indignation and a suggestion for a suitable form of punishment, as follows:

"Of these various frauds so ably exposed in Mr. Accum's work, and which are so much the more dangerous, as they are committed under the disguise of an honourable trade, it is impossible to speak in terms of too strong reprobation; and in the first impulse of our indignation, we were inclined to avenge such iniquitous practices by some signal punishment. We naturally reflect that such offences, in whatever light they are viewed, are of a far deeper dye than many of those for which our sangui-

[5] Vol. 33, pp. 131-144, 1820.

nary code awards the penalty of death—and we wonder that the punishment hitherto inflicted has been limited to a fine. If we turn our view, however, from the moral turpitude of the act, to a calm consideration of that important question, namely—What is the most effectual method of protecting the community from those frauds?—we will then see strong reasons for preferring the lighter punishment. We do not find from experience that offences are prevented by severe punishments. On the contrary, the crime of forgery, under the most unrelenting execution of the severe law against it, has grown more frequent. As those, therefore, by whom the offence of adulterating articles of provision is committed, are generally creditable and wealthy individuals, the infliction of a heavy fine, accompanied by public disgrace, seems a very suitable punishment: and if it be duly and reasonably applied, there is little doubt that it will be found effectual to check, and finally to root out, those disgraceful frauds."

Accum's book did not remain unnoticed in the United States. The review which the editor of the *Analectic Magazine*[6] of Philadelphia gave it was nothing more than republication of one which had appeared earlier that year in Scotland.[7] His single original contribution to the subject is the extraordinary comment with which he introduces the subject. America apparently had no food adulteration problem or, if it existed, the writer chose to remain blissfully ignorant of it! Said he:

"This little work may, in London, be very much useful and wherever meat and bread are eaten, and wine is drunk, or physic taken must be interesting. We cannot help fearing, however, that the distinguished chemist has been laboring unwittingly in aid of fraud rather than for its detection. For one reader that is taught how to avoid adulterated food, ten will have occasion to regret that Mr. Accum has furnished the dishonest vendors with so complete a manual and guide in the manufacture of the most cunningly devised poison. It is, however, whether fortunately or not, presented to the American public. And we consult our own ease and the amusement of our readers at the same time in presenting them with the remarks and analysis made

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6 Vol. 2 [n.s.], pp. 102-129 (1820).

7 *Op. cit.*

by the editors of *Blackwood's Edinburgh Magazine,* instead of any detailed observations of our own."

Mention has already been made of the fact that Accum's book was popularly referred to as "Death in the Pot." The general application of this term as a catch-phrase descriptive of his book was invited, in a sense, on his part because of the motto with which he adorned its title page; and perhaps, too, his use of it in the preface. Doubtless uninvited, however, must have been its application as a nick-name to the author himself.

The following account of an imaginary experience of "a sad, solitary, unsuspecting spinster," which was described in a letter to the editor of *Blackwood's Edinburgh Magazine,*[8] apparently after his review of Accum's book had been read, furnishes an example of the use of the term in this direction.[9] In a somewhat similar vein the writer declared:

". . . I have not the skill in figures to cast up the poisonous contents of my hapless stomach for nearly three-score years. You would not know me now; I had not the slightest suspicion of myself in the looking glass this morning. Such a face! So wan and wobegone! No such person drew Priam's curtain at dead of night, or could have told him half his Troy was burned.

"Well—hear me come to the point. I remember now, perfectly well, that I have been out of sorts all my lifetime; and the causes of my continual illness have this day been revealed to me. May my melancholy fate be a warning to you, and all your dear contributors, a set of men whom the world could ill spare at this crisis. Mr Editor—*I have been poisoned.*

"You must know that I became personally acquainted, a few weeks ago, quite accidentally, with that distinguished chemist, well known in our metropolis by the name of 'Death in the Pot'. He volunteered a visit to me at breakfast, last Thursday, and I accepted him. Just as I poured out the first cup of tea, and

[8] Vol. 6, pp. 621-623, 1820.

[9] Later that year, when Accum stood accused of the impalpable charge of mutilating library books, the following rhyme, entitled "Death in the Pot," appeared in *John Bull* (Dec. 24, 1820, p. 13):

What is his crime? A trick at most,
A thing not worth debating.
—'Tis only what the Morning Post
Would punning call Accum-*ulating*.

was extending it graciously toward him, he looked at me, and with a low, hoarse, husky voice, like Mr Kean's, asked me if I were not excessively ill? I had not had the least suspicion of being so—but there was a terrible something in 'Death in the Pot's' face which told me I was a dead woman. I immediately got up—I mean strove to get up, to ring the bell for a clergyman —but I fainted away. On awakening from my swoon, I beheld 'Death in the Pot' still staring with his fateful eyes—and croaking out, half in soliloquy, half in tête-a-tête, 'There is not a life in London worth ten years purchase.' I implored him to speak plainly, and for God's sake not to look at me so malagrugorously —and plainly enough he did then speak to be sure—*'Mrs Trollope, you are poisoned.'*

" 'Who,' cried I out convulsively, 'who has perpetrated the foul deed? On whose guilty head will lie my innocent blood? Has it been from motives of private revenge? Speak, Mr. Accum —speak! Have you any proofs of a conspiracy?' 'Yes, Madam, I have proofs, damning proofs. Your wine-merchant, your brewer, your baker, your confectioner, your grocer, aye your very butcher are in league against you; and, Mrs Trollope, *you are poisoned!'* 'When—Oh! when was the fatal dose administered?' 'Would an emetic be of no avail? could you not yet administer a —.' But here my voice was choked, and nothing was audible, Mr North, but the sighs and sobs of your poor Trollope."

The unfortunate ending of Accum's long and useful career in London approximately one year after the first appearance of his book was responsible in a measure for a recession of the pure food movement there. An attempt at reviving it is seen some ten years later, however, in the efforts of the anonymous author of "Deadly Adulteration and Slow Poisoning Unmasked; or Disease and Death in the Pot and Bottle."[10]

This book shows an Accum influence not only in the excerpt credited to the *Literary Gazette*,[11] a paragraph which, in turn, is an elaboration of the closing lines of his own preliminary

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[10] Volume I of the British Museum's new *General Catalogue of Printed Books*, 1931, lists this 187-page book under "Adulteration" and assigns to it the publication date 1830. *Gentleman's Magazine* in its October issue for that year on page 349, lists this book under the heading "New Works Announced for Publication." It was reviewed elsewhere the following January.

[11] *Loc. cit.*

remarks, but also in the author's prediction of the reception which would be accorded his efforts. The following lines from his "Address to the Reader" reflect the latter.

"The catalogue of frauds and enormities exhibited in the following pages will, no doubt, excite the abhorrence and indignation of every honest heart. Its author is, however, convinced that he will find that he has undertaken a very unthankful office —that his book will be the dread and abhorrence of wicked and unprincipled dealers and imposters of all kinds; and himself exposed to their utmost rancour and bitterest maledictions. But the die is cast: he has discharged a public duty, and sincerely hopes that the Public may be benefited by his disclosures.

"It has been justly said, that all attempts to meliorate the condition of mankind have, in general, been coldly received, while the artful flatterers of their passions and appetites have met their eager embraces. And it is no less true, that it has always been the fate of those who have attempted any great public good, to be obnoxious to such as have profited by the errors of mankind. The divine Socrates, whose life was a continued exertion to reprove and correct the overweening and the vicious, died a victim to the Heathen Mythology, on account of his maintaining the unity and perfections of the Deity, and exposing the doctrines and pretensions of the heathen priesthood and the Sophists, and their mercenary views; and, in later times, Galileo would have met a similar fate, had he not bowed to error, and renounced a sublime truth, clear as the glorious orb that was the object of it, and which, soon after, was universally acknowledged. Even the Divine Founder of our Faith and Religion was stigmatized as the broacher of false opinions, and one who misled the people, by his ignorant and malicious accusers, whose frauds and delusions it was the object of his mission to confound and overthrow, as well as to free mankind from the bondage of their errors. But without having the presumption or impiety to compare himself with those benefactors of mankind, or to put his humble endeavors in competition with their god-like attempts, or to expect a similar result from them, it will be a great consolation to the Author of this book, when life is departing the frail tenement of his body, to reflect that he has brought 'deeds of darkness to light,'—that he has been the humble means of unmasking to public view the frauds and villanies that are daily and hourly practised on the Public Health and Welfare; and in that 'trying hour' his most grateful feeling and homage to English Law will be, that it secures to every man the liberty of expressing his honest indignation and abhorrence of palpable and disgusting fraud and imposture."

It was not as widely reviewed as was Accum's "Treatise" and, curiously enough, received no appraisal by those journals which had given its precursor this attention. A medical journal, however, quite properly extended the author this courtesy.

The editor of *The Lancet*,[12] "well aware of the great facility with which epidemic terror is excited by tales of the adulterations in food and drink" and deeming it "a duty never to permit a proved fraud of this pernicious description to escape unnoticed," commented as follows upon this work[13] of "an exaggerating alarmist":

"We are equally enemies to needless alarm, and to the too generous confidence which is sometimes reposed on the caterers of the necessaries of existence. It would be difficult, we believe, to determine which of these causes operates with the more injurious influence, and it is under this conviction that we proceed to bestow a few remarks on the publication of the above oddly designated work.

"This strange, but interesting book, is evidently the production of a man of considerable talents, though whimsical mind, and superficial in information on some important particulars. He has followed in the steps of the celebrated Accum to a certain extent, and this notorious author he certainly equals, if he does not excel him, in the industry and sagacity with which he penetrates into the arcana of various trades and mysteries, the deceptions of which, whether actual or pretended, he proclaims to the country in no very complimentary terms. His list of adulterations, as may be seen from the title, forms a lengthened catalogue, and extends almost to every item in our daily consumption. . . .

"One of the most important points to be determined in the consideration of such a treatise as the present, is of course, the veracity of the author; of this, the chief evidence of the affirma-

[12] Vol. I, 1831, p. 485-487.
[13] The date of publication of this book is herein given as 1830.

tive in the case now before us is, in the first place, the want of any evil motive which could induce him to come forward; for, setting a love of mischief out of the question, it may be well supposed that the suppression of such disclosures might be a much more profitable traffic than the sale of the little work in which they are announced. Secondly, he writes in a tone of half-mad honesty, which it is difficult to disbelieve. On the other hand, the principal indications of thoughtless (not to say worse), consist in the absence of names and dates and places from his original statements, in the declamatory and puffing style into which he continually lapses, and in the want of satisfactory chemical evidence on some of the most important particulars. . . .

"Another circumstance, too, which should in some degree diminish our confidence in this writer's authority, is the inaccurate chemical statements he continually thrusts forward, and the utter physiological ignorance he as frequently betrays; thus . . . we find him given credence to the ridiculous story of calves being fed on milk and *chalk*, in order to *whiten* their flesh. . . .

"Under all these circumstances, it is not easy to decide on the light in which this publication should be regarded; our own opinion, however, we have no hesitation in declaring to be, that the author is a correct well-meaning individual, but of that class of exaggerating alarmists, which magnifies terrors of this description to a most nonsensical extent. One service he has at any rate rendered to the public, and to this point we would earnestly solicit the attention of our readers, especially those conversant with analytic researches; he has afforded them, in several examples, a clue to the detection of some infamous deceptions, and has set them, we believe, in the right path for the substantiation of the charges which he vaguely promulgates."

The editor closes his review with the following singular statement in which, in a sense, he appears to condone some of the illegal practices revealed in the book:

". . . we feel it necessary to press upon the general public, that the word 'adulteration' is not necessarily synonymous with injury to health, and that hundreds of these deceptions are practiced with the sole view of baffling the intolerable oppression of fiscal exactions. We can fancy the valetudinarian peruser of a treatise like the present gasping in ignorant horror at the story of his porter being 'adulterated' with quassia, his cheese tinctured with anatto, or his port-wine roughened by the alcohol infusion of tannin; yet these substitutions, though less delicate to the epicure's taste, are as free from any noxious quality in the proportions in which they are employed, as the most genuine article which can be procured. If writers on this subject separated the noxious from the harmless, and dealt not so much in hyperbolical declamation, there would, at the same time, be less terror created, and the ends of public justice would be more effectually attained."

The *New Monthly Magazine and Literary Journal*[14] on the other hand accepted, without question, all of the statements made in the book. Said the reviewer:

"'Deadly Adulteration and Slow Poisoning, or Disease and Death in. . . .' We cannot proceed farther with the alarming title-page of this small but eventful volume, the production of 'An Enemy of Fraud and Villainy.' It is a treatise not to be read with firm nerves, or, we may add, with a wavering faith. It is a most portentious catalogue of calamities; and shows us (we are afraid we must believe it all) how impossible it is to escape death and destruction in some degree or other. We have long known how many ways there are of dressing an egg; we are now convinced that there are just as many ways of poisoning people. The writer of this little work has pointed out such numberless instances of what he terms 'blood-empoisoning and life-destroying adulterations,' pervading every luxury and necessary of life, that we begin to feel surprised that the world has lived so long; and must now express the opinion that he who desires to survive longer must forego a practice which he has hitherto considered essential to existence—he must cease to eat and drink. A third part of the book is devoted to an exposition of abuses in the manufacture of wine, spirits, and beer; the remaining portions are employed in an analysis of nameless and unnatural matters which we have hitherto considered to be flour, tea, spice, confectionery, medicines, &c. &c. but whose real quality and character we shudder to contemplate. It is clearly the opinion of the writer before us, that there is nothing

14 Vol. 33 [n.s.], p. 18, 1831.

in the world free from quackery but his own production. Nevertheless, we honestly recommend it; for if people must be poisoned, it is but right that they should know how—unless they should think, with the poet, that ignorance is bliss, as in this instance we believe it to be."

The attempts of Accum and others "at unmasking to public view the frauds and villanies—practiced on the public health and welfare" were soon forgotten. The generation following them had apparently heard little of the much publicized "Death in the Pot" or, conversant with the contents of this little treatise, chose not to take it seriously. It had little effect in reforming the abuses which it exposed. In spite of the startling revelations which this remarkable book contained, fraudulent tradesmen and manufacturers silently, and with some measure of security, continued to falsify the food of the people and to pocket their ill-gotten gains.[15] This was the situation when in 1851, a new force in the person of a member of the medical profession took up the task so enthusiastically begun some thirty years before by Accum but abruptly terminated by his unhappy return to Germany.

In the first issue of *The Lancet*[16] for the year 1851 appeared an announcement in which the editor committed this journal to a new departure. Apparently sensing the apathy of the medical profession to the notorius and systematic adulterations practiced upon the food of the people—an attitude deemed to reflect no credit upon it—and suspecting these practices contributive to various human disorders,[17] he stated that henceforth some of his columns would be devoted to the publication of the findings of the Analytical Sanitary Commission. It is quite probable, too, that a statement[18] previously made by the Chancellor of the Exchequer in the House of Commons that distinguished chemists of the day had reported that neither by chemistry nor in any other way could the admixture of chicory with coffee be detected may have been another motivating agent in the editor's decision to institute this innovation. In any event it was soon

[15] A. W., *Once A Week*, vol. 2, p. 396-399, 1860.
[16] Vol. 1, 1851, p. 18.
[17] *Ibid.*, p. 17.
[18] Anon., *Analyst*, vol. 19, p. 97-98, 1894.

to become apparent that chemistry did not accept the challenge implied in this statement.

In reality, this body of impressive title was not a commission at all. It consisted solely of Dr. Arthur Hill Hassall, an expert microscopist but neither chemist nor analyst in the modern sense of the word in as much as his training in chemistry had been no more intensive than that received by any medical student as incidental to the prescribed course of study of his day. Hassall in time found it necessary to add to this method of examination that of chemical analysis and for that portion of the work obtained the assistance of a trained analyst. Because of his work in this field, the results of which for the next four years appeared first as separate reports and then in book form as "Food and Its Adulterations," he became for a time the chemical oracle[18] of the public, and this upon the basis of his microscopic work "which was in every way excellent."

The public mind was deeply impressed by Hassall's reports; their disclosures produced a feeling of most profound astonishment[19] over the violation of "those principles of integrity which ought to be characteristic of all commercial transactions." London's *Punch* commented at times on the situation with many a quip and witticism. The following, captioned "Death in the Jam-Pot,"[20] is a case in point.

"The Analytical Commissioners of the *Lancet* have been dipping their fingers lately into the preserve pots of the Metropolis, and '*Ohe, jam satis!*' must, we fancy, be the exclamation of everybody who reads their Report. For, among other pleasant discoveries, we find it stated,—'That copper was detected in no less than 33 of the 35 samples of different preserves analysed; —'

"Preserve us from preserves, say we, in future! Even as it is, we own an introspection makes us anything but comfortable, and we tremble to think of how many internal coats of copper we may incautiously have given ourselves. In our fondness for the jam, we fear indeed we have been playing 'old gooseberry' with our constitutions; and we should certainly be making very decided gooseberry fools of ourselves if we were any longer to partake of it.

[19] *The Lancet*, vol. 1, 1851, p. 72.
[20] *Punch*, vol. 24, p. 107, 1853.

"Before the *Lancet's* searching fingers
Had found the limes where copper lingers,

that fruit, we confess, was a confirmed weakness of ours; but the 'little glass jar,' which was analysed as above, has proved quite a jar of electricity to us, such a shock has it imparted to our nervous system. Nor have we any longer an appetite for crystallised green gages: for, knowing now to what they owe their colour, we should be 'deep green' ourselves if we ventured any more to taste them.

"With the above appalling facts before them, we would seriously recommend any of our readers who may have a 'sweet tooth' in their heads, to go immediately to the dentist's, and have it out. There is no telling how soon it may eat them into danger."

Soon there followed the appointment of a Committee in Inquiry by the House of Commons and ultimately, in 1860, the enactment of a general law against the adulteration of all foods. This statute constitutes the keystone of the pure food and drugs law of the English-speaking world.

By 1879 the movement for reform in the commerce in foods appeared in the Congress of the United States. After a 27-year effort, during the course of which 74 bills were introduced—16 were reported out of committee and three survived one branch of Congress—one was at last passed. The final push to a successful conclusion of the fight was given by the women of the United States; the result is the Pure Food and Drugs Act of June 30, 1906.

Contributive, perhaps, to this campaign in its early days was a cartoon in color by Opper,[21] and its accompanying editorial comment, "Look before you eat." Both have sufficient historical interest to warrant reproduction.

"Come with us, O Friend! to the feast. There you will be enabled to tickle your palate with all the delicacies of the season. See what a bounteous repast is spread before you. Sugar from the golden canes of Cuba, turned out ready for consumption. Sugar, did we say? Well, not exactly. It looks like sugar,

[21] Vol. 15, March 18, 1884, p. 17. Earlier factors in this movement were the famous crusade by *Frank Leslie's Illustrated Newspaper* (May 8, 1858, *et seq.*) against the swill milk system of New York and Brooklyn and the vigorous exposition, begun ten years later by the *New York World* (Dec. 17, 1868 *et seq.*), of the adulteration of foods.


Cartoon by Opper which appeared in *Puck*, vol. 15, March 12, 1884, p. 17.

but it bears only a partial relationship to the genuine article. If you examine it carefully, you will arrive at the conclusion that that sugar has started the summer season prematurely, and has collaborated with what is left of the beach at Coney Island. The sugar is full of sand, and the grocer who sold it to the customer has long ere this discovered that sand is ever so much cheaper than sugar.

"But sand and sugar are not as wholesome as sugar itself; at least many people have a strong prejudice against the combination—when they find it out. Now, let's take a glance at the butter. How attractive is its appearance! It is the best creamery, is it not? No, beautiful Heloise, it is not the best creamery. The grocer of whom you bought it may have assured you that it is; but that grocer is not a George Washington in regard to his affection for truth. No, beloved friend, that is not the best creamery butter; it is pure, unadulterated oilymargarine made out of finest and fattest carcasses of animals secured by the rendering establishment, a premium given on those that have died a natural death. The tea, too, has its deleterious dust, that it may yield a greater profit to the seller; so has the coffee; so has everything else. The grocery-man's inhumanity to man will soon make it necessary for every citizen to carry with him a stomach-pump and an emetic."

# THE INFLUENCE OF SCIENCE ON AMERICAN IDEAS, FROM 1775 TO 1809*

HARRY HAYDEN CLARK

The roots of the basic ideas of the latter part of the eighteenth century in America, as I have tried to suggest elsewhere,[1] are many and various. Among them, helping to undermine Puritanism, are such divergent influences as classicism, Quakerism and Methodism, primitivism, the idea of progress, the frontier environent, agrarianism, laissez-faire, French democracy, sentimentalism and humanitarianism, Gothicism, and aesthetic programs involving the quest of the strange, the unique, the local, the sensuous. Surely it would be a serious error to imagine that ideas inspired by science *alone* explain American ideas of this period. Until very recently, however, science, and deism partly inspired by science, have been largely ignored by students of American literature of the late eighteenth century. Puritanism and Transcendentalism have long been recognized as dominating the literature of their eras, but one looks in vain, in practically all our textbooks, for a parallel emphasis on the religion of the intermediate period (deism influenced by science) as underlying the ideas of the era when our national traditions took shape. Representative liberals such as Tom Paine prided themselves upon their method of considering everything "on the pure ground of principle, . . . abstractedly from custom and usage," and if one tries to formulate the logical articulation of their principles, it will be found, I think, that more than generally recognized, many of these principles trace themselves back to major premises used by Newton, Locke, and the popularizers of scientific doctrine.

Students interested in this problem will find many fruitful

* It is a pleasure to acknowledge gratefully that clerical assistance was provided for this study by the Wisconsin Academy of Sciences, Arts and Letters, and by the Graduate School of the University of Wisconsin.

[1] "Factors to be investigated in American Literature History from 1787 to 1800," *English Journal*, XXIII, 481-87 (June, 1934).

suggestions in the studies of the debt of English literature of this period to science and related subjects. I have in mind studies by such scholars as S. G. Hefelbower,[2] A. Wolf,[3] Leslie Stephen,[4] G. R. Potter,[5] A. O. Lovejoy,[6] Ronald Crane,[7] J. M. Robertson,[8] John Orr,[9] L. E. Hicks,[10] A. S. Farrar,[11] G. V. Lechler,[12] L. Noack,[13] J. W. Beach,[14] Norman Torrey,[15] Herbert Drennon,[16] C. S. Duncan,[17] Martha Ornstein,[18] R. F. Jones,[19] O. H. Taylor,[20] Jacob Viner,[21] A. D. White,[22] Leon Bloch,[23] Dorothy Stimson,[24] R. B. Crum,[25] and others.

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[2] *The Relation of John Locke to English Deism.* Chicago, 1918.

[3] *A History of Science, Technology, and Philosophy in the Sixteenth and Seventeenth Centuries.* 1935.

[4] *A History of English Thought in the Eighteenth Century.* London, 1902.

[5] *Strange Gods Come to Parnassus.* A Study of the Relations between the English Poets and Evolutionary Ideas from pre-Darwinian Science. (A volume not yet published which I have been permitted to read in manuscript.)

[6] "The Place of Linnaeus in the Unfolding of Science," *Popular Science Monthly.* LXXI, 121-130, 1907; "Some Eighteenth Century Evolutionists," *Popular Science Monthly,* LXV, 238-51, 323-40, (1904). *Ibid.,* LXXV, 499ff., 537ff., 1909; *The Great Chain of Being.* Cambridge, Mass., 1936. "Monboddo and Rousseau," *Modern Philology,* XXX, 275-96 (Feb. 1933).

[7] See his many reviews in his annual bibliography in *Philological Quarterly.* In his "Angelican Apologetics and the Idea of Progress," *Modern Philology,* XXXI, 273-306; 348-82 (Feb. and May, 1934), Mr. Crane has shown that the idea of progress derived not only from science but from the clerical opponents of pessimistic doctrines disseminated by Hobbes and his followers.

[8] *A Short History of Free Thought, Ancient and Modern.* Vol. II, London, 1915.

[9] *Eighteenth Century English Deism and Its Sources.* (A dissertation in manuscript summarized in the *University of Pittsburgh Bulletin,* Vol. 28, No. 4, Dec. 1931.

[10] *A Critique of Design-Arguments.* New York, 1883.

[11] *A Critical History of Free Thought in Reference to the Christian Religion.* New York, 1864.

[12] *Geschichte Des Englishen Deismus,* Stut. 1841.

[13] *Die Freidenker in der Religion.*

[14] *The Concept of Nature in Nineteenth Century English Poetry.* New York, 1936.

[15] *Voltaire and the English Deists.* New Haven, 1930.

[16] "Newtonianism: Its Method, Theology, and Metaphysics," *Englische Studien,* LXVIII, 397-409 (1933-34). Other parts of Mr. Drennon's brilliant dissertation, *James Thomson and Newtonianism* (University of Chicago, 1928) have been published in *Publications of the Modern Language Association,* XLIX, 71-80, March, 1934; in *Studies in Philology,* XXXI, 453-71, July, 1934; and in *Philological Quarterly,* XIV, 70-82, Jan., 1935.

[17] *The New Science and English Literature in the Classical Period.* Menasha, Wis., 1913.

[18] *The Rôle of Scientific Societies in the Seventeenth Century,* New York, 1913.

[19] *Ancients and Moderns.* Washington University Studies. New Series. Language and Literature, No. *6,* Jan., 1936.

[20] "Economics and the Idea of Natural Law," *Quarterly Journal of Economics,* XLIV, 1-39 (Nov. 1929). See also the outline of his valuable dissertation in the Harvard University *Summaries of Theses* (1928), 102-6.

[21] *Adam Smith, 1776-1926.* Chicago, 1928.

[22] *A History of the Warfare of Science with Theology.* 2 vols. New York, 1896.

[23] *La Philosophie de Newton.* Paris, 1908.

[24] *The Gradual Acceptance of the Copernican Theory of the Universe.* Hanover, N.H., 1917.

[25] *Scientific Thought in Poetry.* New York, 1931. See also Basil Willey, *The Eighteenth Century Background* (London, 1939) and A. O. Lovejoy's review in *MLN,* LVIII, 485-7; and May Bush's "Rational Proof of a Deity from the Order of Nature," *ELH,* IX, 288-319 (Dec. 1942).

It is significant that Elie Halévy traces the growth of English philosophical and social radicalism to two major causes: to "The development of the physical sciences" (especially Newtonianism) and to a "profound crisis in society, a crisis which was itself due in part to the development of science and to the progress of its practical application."[26] The channels by which English and Continental ideas made their way to America and were disseminated here remain to be exhaustively explored. Among these channels, however, were the activities of scientific societies, notably the Royal Society (to which 19 Americans were elected before 1800)[27] and the American Philosophical Society; the emigration to America of scholars trained in European universities; the international correspondence of scientists; American travelers abroad; almanacs and magazines and libraries; public lectures; and schools and colleges. In England, of course, science did not always develop into political or social liberalism, but in America not only did the novelty of a fresh environment inspire scientific interest but scientific ideas paralleled the democracy engendered by the frontier and the resentment against restrictive governmental acts by England. Considering the vast field covered in this brief paper, I shall attempt not so much a contribution to knowledge or an exhaustive analysis as a statement of hypotheses as a means of opening what ought to be a fruitful avenue for investigation. I shall discuss in turn religious, political, humanitarian, and educational ideas in their relation to science.

## I

## Religion

Puritanism and scientific deism are sharply distinct in their development. One must guard, however, against the impression

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[26] *The Growth of Philosophic Radicalism.* (Translated by M. Morris.) London, 1928, p. 3.

[27] The list will be found in S. E. Morrison's *Pronaos.* New York, 1936, p. 266. For full discussion see F.E. Brasch, "The Royal Society of London and its Influence upon the Scientific Thought in the American Colonies," *Scientific Monthly,* XXXIII, 336-55, 448-69 (1931). For general discussion see B. Faÿ's "Learned Societies in Europe and America in the eighteenth century," *American Historical Review,* XXXVII, 255-66 (Jan. 1932); and G. B. Goode's The Origin of the National Scientific and Educational Institutions of the United States," *Annual Report* of the . . . Smithsonian Institution (1897), pp. 263-354; "The Beginnings of Natural History in America," *ibid.,* 357-406 and "The Beginnings of American Science," *ibid.,* 409-466.

that the transition from one to the other was immediate or violent. This transition was a very gradual affair in which many thinkers seem at certain times to have been on both sides at once, as in the case of Cotton Mather in his *Christian Philosopher* (1721). It has been demonstrated, in a dissertation by Mr. Theodore Hornberger,[28] that it is a serious error to suppose that American Puritans were unreceptive to science and scientific ideas until the 18th century. Puritanism did not retard the spread of scientific ideas in America. On the contrary, the Puritans showed much interest in scientific ideas. The idea of cosmic design proving a divine designer goes back of course much beyond the Puritans. The ancient Hebrews thought that "The Heavens declare the glory of God," and the argument from design had appeared in Cicero, Sir Henry More, Cudworth, Boyle, and Ray, and it was widely popularized and elaborated by the Rev. William Derham's *Physico-Theology; or, a Demonstration of the Being and Attributes of God from his Works of Creation* (1711-1712). In connection with the Puritans,[28a] it should be remembered, that from Calvin down, their leaders devoted increased attention to the doctrine that the Creator is revealed in his Creation, in nature; but they united in thinking, that a knowledge of nature alone was an inadequate guide to a religious life. As Calvin said, "The guidance and teaching of the Scriptures [are] necessary to lead to the knowledge of God the Creator."[29] The Puritans thus devoted their chief attention

[28] *American Puritanism and the Rise of the Scientific Mind. A Study of Science and American Literature in the Seventeenth and Early Eighteenth Centuries.* (A doctoral dissertation available in manuscript at the library of the University of Michigan.) For bibliography, see P. Miller and T. H. Johnson, *The Puritans* (New York, 1938), pp. 823-29.

[28a] Cf. Michael Wigglesworth's familiar lines in "The Day of Doom": "But Nature's light shin'd not so bright, to teach us the right way." (Stanza CLXI).

[29] It is true that Calvin spoke of sciences such as astronomy as studies of the "proofs" of God's "Wonderful wisdom, both [in] heaven and earth." But this passage (*Institutes*, Trans. J. Allen, 2 vols., 1841, I, V, 2, pp. 58-9), which is often cited out of its context in a very misleading way, is immediately followed by Chapter VI, for which the sentence quoted above, on the primary necessity of Scriptural guidance, serves as the title. In *Institutes*, Bk.I, Ch.V, xiv-v, Calvin said "Vain, therefore, is the light afforded us in the formation of the world to illustrate the glory of its Author, which, though its rays be diffused all around us, is insufficient to conduct us into the right way. . . . It is beyond a doubt, that the simple testimony magnificently borne by the creatures to the glory of God, is very insufficient for our instruction." The typical view of the New England Puritans may be illustrated from this passage in Norton's *Heart of New-England Rent* (pp. 12-13): "Star-light cannot make it, otherwise than night. The light of nature since the fall, compared with the light of the image of God, before the fall, hath not the production of Star-light, to the bright sun at noon-day. This is indeed but darkness. But if compared with the light of the Gospel, it is worse than gross darkness."

not to the study of nature through science but to the study of the Scriptures—a linguistic study. In the second place, when, as in the case of Cotton Mather's *Christian Philosopher* (1721), or his writings slightly earlier, a Puritan emphasizes the value of the study of goodness, design and beauty in nature as a revelation of God's goodness, he thinks of the study of nature through science as reinforcing and in no way refuting Scriptural revelation.[30] This reconciliation of Scripture and nature as the source of religious knowledge was not peculiar to Puritans such as Cotton Mather. Tindal, for example, a typical English deist, entitled his influential book *Christianity Old as the Creation: Or the Gospel a Republication of the Religion of Nature* (1730), and he emphasized reliance on reason. Gradually the Puritan faith in miracles and unpredictable, illustrious providences gave way in American society to the deistic faith that reason invalidated miracles and that the deity, having ordained the immutable laws of the world-machine, could no longer interfere. The crux of the problem involved in the transition from Puritanism to Deism in America is not the question, "When did men see Creation as revealing a Creator," but "When did they come to believe that the Creation reveals a Creator in a way which makes belief in the Scriptural revelation unnecessary, if not impossible?" The essence of deism, as Professor Crane has said, involves "the complete lack of authority of any religious beliefs which cannot be shown to have been held everywhere, in all ages, and by all men."[31]

Yet one must distinguish, following Leslie Stephen, between "constructive deists" and "critical deists"—the latter of whom insisted sharply that the findings of science in nature invalidate Biblical doctrines of revelation. Newton himself of course revered the Bible; but some of his doctrines, in the era of the French Revolution, were turned against[31a] Christianity by his

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[30] This subject has been well treated by T. Hornberger in his article entitled "The Date, the Source, and the Significance of Cotton Mather's interest in Science," *American Literature*, VI, 413-420 (Jan. 1935). See also K. B. Murdock's Introduction to *Selections from Cotton Mather*, N.Y., 1926, especially pp. xlviii-liv.

[31] R. S. Crane, "Anglican Apologetics and the Idea of Progress," *Modern Philology*, XXXI, p. 350 (May, 1934).

[31a] William Scales, F.R.S., in 1806 attacked Harvard as a "seminary of sophistry, falsehood and folly" furthering infidelity by means of science: "As soon as I applied myself to study, great Locke was delivered to me, to study whom I found to be a miserable destroyer of the under-

later interpreters. Samuel Keimer's *Universal Instructor in all Arts and Sciences* (Philadelphia) has been interpreted as "A Brand Flung at Colonial Orthodoxy":[32] as early as 1729 he developed the doctrine that God is "to be known *only* in his *Works*," in nature seen through the eye of science. The most violent of the critical deists, however, is of course Tom Paine, who said that "the two faiths [Christianity and science] cannot be held together in the same mind,"[33] that whoever believes in Christ is an infidel. But Paine's violent rejection of Christianity is approached by that of Ethan Allen's *Oracles of Reason*,[34] and traces of this rejection of Christian orthodoxy in the name of scientific rationalism can be found in Franklin (as early as 1728), in Thomas Cooper, in Jefferson and in Freneau. The typical scientific deist,[35] then, is regarded in this paper as not merely one who thinks the design of nature a revelation of a designer. Of course not all deists were "scientific," but in America science played an especially important rôle.

Let us begin with Franklin's religion. He had been born in Puritan Boston and reared "piously in a dissenting way." However, as a result of reading "Shaftesbury and Collins" and some of the Boyle lectures, Franklin said that he become a "thorough

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standing; after that, renowned Sir Isaac Newton came before me for examination, and I found him a great fabricator of falsehoods, and a destroyer of the work of God." (Dedication in Scales' "The Quintessence of Universal History.")

[32] See discussion by C. E. Jorgenson in his article, "A Brand Flung at Colonial Orthodoxy," *Journalism Quarterly*, XII, 272-277 (Sept. 1935). The dissemination of deistic ideas and Newtonianism is also treated in Jorgenson's "Almanacs of Ames and Franklin," *New England Quarterly*, VIII, 555-61 (Dec. 1935).

[33] *Writings of Thomas Paine*, edited by Conway, IV, 66.

[34] For discussion see Woodbridge Riley, *American Philosophy, The Early Schools*, New York, 1907; and G. A. Koch, *Republican Religion*, New York, 1933, pp. 28-50; G. P. Anderson (*N. E. Quarterly*, X, 685-96) argues that a Philadelphia physician, Dr. Thomas Young, wrote most of the *Oracles*.

[35] It should be borne in mind that scientific deism is but part of the philosophy of The Enlightenment, which involved faith in reason, in progress, in natural altruism, and in man's power to perfect himself by modifying his outward environment. (See Carl Becker, *The Heavenly City of the Eighteenth Century Philosophers*, New Haven, 1932, p. 102, and Preserved Smith, *A History of Modern Culture*, New York, 1934, Vol. II, with elaborate bibliography. In so far as deism involved a return to what all men in all times have accepted as basic and universal, it drew occasionally upon classical doctrines, particularly those represented by Cicero. Conyers Middleton, for example, the English deist, was much indebted to Cicero and wrote his biography. And Thomas Paine (*Writings*, IV, 410) cited Cicero's doctrine of the law of nature (*De Legibus*, II, 4, 10) by way of Middleton. But this was in 1807, two years before Paine's death, and long after he had formulated his deism in *The Age of Reason*, where he expressly states his primary debt to science.

deist."[36] Inspired by an attempt to refute Wollaston, he devoted his *Dissertation on Liberty and Necessity,* as early as 1725, to an attempt to prove that, because God is both "all-good, all powerful," and the universe is balanced and it is operated by immutable law, "the distinction of Virtue and Vice is excluded." In his mechanistic and rationalistic *Articles of Belief* (1728) Franklin modifies the radical views just mentioned, but he insists that the deity and his will are adequately revealed in nature, and that, as opposed to ecclesiastical embroidery, one need believe only what men in all times and lands have believed. Entranced by the harmonious "chorus of planets moving periodically by uniform laws," Franklin thinks God "has given us Reason whereby we are capable of observing his Wisdom in the Creation." "Thy Wisdom, thy Power, and thy Goodness are everywhere clearly seen; in the air and in water, in the Heaven and on the Earth." Elsewhere he saw "the best *Histories of Nature*" as "new Proofs of Divine Providence," and he repeatedly urged us to read "the sacred Book of Nature" as the source of "what is Right."[36a] Franklin relies, then, not on traditional authority or ecclesiasticism, but upon "the everlasting tables of right reason" as the interpreter of the sacred and "mighty volumes of visible nature." He venerated Jesus's morals, but had "doubts as to his divinity,"[37] and he did not accept the Scriptures as a divine revelation. In these ways, then, he departed from orthodox Christianity, relying upon scientific rationalism with which, as Turgot said, he snatched sceptres from kings and lightning from the Puritan heaven, where it had been the symbol (to men like Edwards) of a capricious, "angry" God.

His friend Thomas Jefferson eventually evolved into a Unitarian and looked upon himself as a liberal Christian,[38] who,

[36] For elaborate discussion of Franklin's scientific deism in relation to his other interests, see introducton to *Franklin* (1936) by F. L. Mott and C. E. Jorgenson, and studies listed in their bibliography by Seipp, Stifler, Bruce, etc.

[36a] Franklin's *Writings* (ed. Smyth), II, 169 and 395; Mott and Jorgenson, pp. 132-3, 160-1, 205.

[37] Franklin summarizes his "Creed" in his letter to Ezra Stiles, March 9, 1790, found in the Smyth's edition of Franklin's *Writings*, X, 83-85.

[38] His later views will be found discussed by W. D. Gould, "The Religious Opinions of Thomas Jefferson," *Mississippi Valley Historical Review*, XX, 191-209 (Sept. 1933), and by Gilbert Chinard, *Thomas Jefferson* (Boston, 1929), pp. 513ff. His earlier and more radical views are discussed in W. Riley, *American Philosophy*, who summarizes his religion as "an eclecticism of a pronounced deistic type."

following Priestley, had rescued the diamond from the dunghill of ecclesiastical corruption. During his most active life, however, he was essentially a deist who quoted approvingly Bolingbroke's idea that the "heathen moralists" were "more full, more entire, more coherent than Christ."[39] He had a fierce hatred of Calvinism and all its doctrines.[40] Confident that "reason is the only oracle,"[41] that whatever would "contradict the laws of nature" should be questioned, Jefferson, as an ardent admirer of Newton, developed the belief ("without appeal to revelation") that the "design" of the universe, manifest in "the movements of the heavenly bodies" maintained in harmonious order, bespeaks "a Fabricator of all things from matter and motion, their Preserver and Regulator."[42] It is true he cited religious doctrines from the ancient classics, but Professor Chinard[43] has shown that he took from the classics only those ideas which would not conflict with his basic deism, which (as the above quotations suggest) appears to have been mainly inspired by Newtonian astronomy. From his faith in reason as the basis of science[44] (to be cultivated by universal education) and his faith in the influence of environment upon character (based on the *tabula rasa* doctrines of Locke's psychology) he derived in part at least his faith in the potential goodness of the people; this, being the seminal principle of his democracy, will be more fully discussed in our later section on Politics. It seems probable, although the evidence is hardly conclusive, that he was not uninfluenced by the harmony and rationality of the Newtonian

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[39] *The Literary Bible of Thomas Jefferson*, ed. Chinard, (Baltimore, 1928), p. 58.

[40] See *Best Letters of Jefferson* (Boston, 1926), pp. 228-29; 251-56. For exhaustive evidence, see the doctoral dissertation (which I directed) by Barriss Mills on *Nineteenth Century American Attitudes toward Puritanism* (1941. University of Wisconsin Library).

[41] *Ibid.*, 36.

[42] *Ibid.*, 252-53.

[43] Chinard, *Literary Bible*, p. 16.

[44] For studies of various aspects of Jefferson's interest in science see A. W. Greely, "Jefferson as a Geographer," *National Geographic Magazine*, VII, pp. 269-271, 1896; Fred Lucas, "Thomas Jefferson—Palaeontologist," *Natural History*, XXVI, 328-30 (June, 1926); G. T. Surface, "Investigation into the Character of Jefferson as a Scientist," *Journal of American History*, IV, 214-20, and the same author's "Thomas Jefferson: A Pioneer Student of American Geography," *American Geographical Society Bulletin*, XLI, 743-50 (Dec. 1909); R. H. True, "Thomas Jefferson in Relation to Botany," *Scientific Monthly*, III, 345-60 (Oct. 1916); J. W. Wayland, "Jefferson as a Scientist," *Virginia Journal of Science*, XIX, 358-59. He made especially important contributions to science in fathering the Lewis and Clark Expedition as a means of gathering data regarding geography and our distinctive flora and fauna, and in administering (while Secretary of State) our first Patent Office as a means of encouraging scientific inventions.

system in his belief that men may be educated to be rational and good,[45] that self-love and social are the same. It may not be entirely fanciful to suppose that his fundamental agrarianism[46] which came to him partly by way of the scientific and deistic French physiocrats, was partly influenced by his religious faith that nature (and not the Bible) is a divine revelation. Finally, his dominant faith in progress is strongly conditioned by rationalistic science.

I have tried to analyse elsewhere[47] Tom Paine's religion as it is indebted to science, notably Newtonian doctrines as popularly interpreted by Benjamin Martin and James Ferguson, to whose lectures he listened at the formative age of twenty. "The natural bent of my mind," Paine said, "was to science."[47a] In summary, it may be said that, completely rejecting Christianity, Paine held that (A) outward nature, in the eye of science, is the only revelation of a Creator who is benevolent; (B) the scientific study of nature reveals, also, a "harmonious, magnificent order";[48] nature . . . is the laws the Creator has prescribed to matter";[49] (C) the natural man shares the divine benevolence, is instinctively altruistic, and in this harmonious order his "wants, acting upon every individual, impel the whole of

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[45] *Best Letters*, 257; 177-78; *Writings* (ed. Bergh), XIV, 43.

[46] See discussion in V. L. Parrington, *Colonial Mind*, New York, 1927, pp. 342-56, and in G. Chinard's introduction to his edition of the *Correspondence of Jefferson and Du Pont de Nemours*, Baltimore, 1931. Jefferson wrote, "I think our governments will remain virtuous . . . as long as they are chiefly agricultural; and this will be as long as there shall be vacant lands in any part of America. When they [the people] get piled upon one another in large cities, as in Europe, they will become corrupt as in Europe" (*Writings*, ed. Ford, IV, 479-80, Dec. 20, 1787). It would appear, then, that his basic democratic faith in the goodness of the people rests upon his frontier agrarianism and the not unrelated *deistic* view that the earth is a divine revelation and contact with it (as in the farmer's life) promotes virtue.

[47] H. H. Clark, "An Historical Interpretation of Thomas Paine's Religion," *University of California Chronicle*, XXXV, 56-87 (Jan. 1933). In a brief sketch, "Toward a Reinterpretation of Thomas Paine" (*American Literature*, V, 133-45, May, 1933) I have tried to suggest the manner in which Paine's scientific deism inspired his political, economic, humanitarian, educational, and literary ideas. Marjorie Nicolson, an outstanding authority on the influence of science on literature, has shown that Paine's ideas, especially in the *Age of Reason*, Part I, came to him "from the 'new astronomy' of the seventeenth and eighteenth centuries," and that "the central doctrine upon which the *Age of Reason* is founded" is the doctrine of the plurality of worlds which made disbelief in Christianity "a logical and inevitable conclusion from indisputable scientific premises." (See her scholarly study, "Thomas Paine, Edward Nares, and Mrs. Piozzi's Marginalia," in *The Huntington Library Bulletin*, No. 10, Oct., 1936, especially pp. 108, 111, 113.

[47a] Paine's *Writings* (ed. Conway), IV, 63.

[48] *Ibid.*, IV, 340.

[49] *Ibid.*, IV, 339; also 242; 311.

them into society, as naturally as gravitation acts to a centre;[50] (D) an attempt to re-establish in thought and action the lost harmony with this uniform, immutable, universal, and eternal law and order which is nature, and to modify or overthrow whatever traditional institutions have obscured this order and thrown its natural harmony into discord, will constitute progress, will radically decrease human suffering, and will rapidly usher in "the birthday of a new world."[51] The important thing to remember is that when the deistic Paine proposed a program of back-to-nature he did not mean to go back to a primitive wilderness but to try to approximate in civil society the law and order of the Newtonian universe. Nature means law and order; it does not mean anarchy. Although the *method* of using analogies between the natural and political orders may have been essentially Platonic, the central definition of his program seems to have been strongly colored by Newtonian science.

## II

## Politics

Having now surveyed briefly the manner in which science entered into American religious thought, let us now inquire into the way in which analogies with science and ideas inspired by science entered into American political thought. First a word as to Old World backgrounds. Dr. Herbert Drennon, in his Chicago dissertation,[52] has surveyed the interesting manner in which Newtonian ideas of the immutability and universality of natural law as a divine revelation had been popularized by such men as Bentley, Samuel Clarke, William Derham, Pemberton, David Gregory, John Keill, William Whiston, Colin MacLaurin, Locke, John Woodward, J. T. Desaguliers, Joseph Addison, Sir Richard Blackmore, Henry Needler, and John Hughes. Voltaire's *Elemens de la philosophie de Newton* was translated and

[50] *Ibid.*, II, 406. The suspicion that Paine is here merely using a figure of speech seems untenable when one considers his statement in the light of the whole *Age of Reason* which, as Miss Nicolson shows, is permeated with ideas derived from science.

[51] *Ibid.*, I, 119.

[52] Summarized in *University of Chicago Abstracts of Theses*, Humanistic Series, 1930, VII, 524 ff.

published in English the very year it had originally appeared, 1738; Voltaire's vogue in America, like that of the other French spokesmen of the Enlightenment,[53] was considerable. The manner in which scientific law and government were being connected[54] is apparent in the following confession by Desaguliers: "I have considered Government as a Phenomenon, and look'd upon that Form of it to be the most perfect which did nearly resemble the Natural Government of our System according to the laws settled by the All-wise and All-mighty Architect of the Universe." This statement occurs in the preface to Desaguliers' poem of 1728 entitled "The Newtonian System of the World, the Best Model of Government: an Allegorical Poem. . . ."[55] Such analogies between politics and Newtonianism were doubtless brought to America by men such as Isaac Greenwood, who, after listening to Desaguliers' astronomical lectures in London, gave popular lectures on astronomy at Harvard.[56] The younger John

[53] For discussion see Mary S. Libby's *The Attitude of Voltaire to Magic and the Sciences*. New York, 1935. And see Mary Margaret Barr's *Voltaire in America, 1744-1800* (Baltimore, 1941) and the review of it by D.F. Bond in *Modern Language Quarterly*, III, 144-6 (March, 1942). For general backgrounds see Kingsley Martin, *French Liberal Thought in the Eighteenth Century: A Study of Political Ideas* (Boston, 1929); Bernard Faÿ, *The Revolutionary Spirit in France and America* (New York, 1927); H. M. Jones', *America and French Culture* (Chapel Hill, N.C., 1927), especially chapters XIV and XV on politics; and the elaborate "Bibliographical Essay" characterizing a host of modern studies in Crane Brinton's *A Decade of Revolutions* (New York, 1934) pp. 293-322. It is significant that Timothy Dwight should have dedicated his satirical *Triumph of Infidelity* (1788) to Voltaire.

[54] For further evidence which shows the manner in which contemporaries were taking the harmony of the Newtonian system as the analogy of an ideal social order, see George Berkeley, *The Guardian*, No. 126, Wednesday, Aug. 5, 1713 (from Chalmers, Vol. XVIII, 15ff): Thomson's *Liberty* Part V (where "this social cement," this "moral gravitation," keeps society from being drawn "to several selfish centers" just as gravitation keeps the physical world from reverting to chaos); *The Works of Richard Bentley* (ed. Dyce, London, 1838), III, 266-79, "A Sermon Preached before King George I on February the third, 1716-17," where he argues that just as gravitation binds the physical world together, so an analagous "public principle" implanted by God binds members of society together harmoniously. From another angle science influenced political theory through anthropological observations of travelers: see John L. Myers' study of "The Influence of Anthropology on the Course of Political Science," in the *University of California Publications in History*, Vol. IV, (1916-17), pp. 1-81. He treats especially such authors as Locke, Voltaire, and Rousseau. This president of the Anthropological Section of the British Association of Scientific Advancement concludes, p. 74, that the evidence shows "how intimately the growth of political philosophy has interlocked at every stage with that of anthropological science. Each fresh start on the never-ending quest of *Man as he ought to be* has been the response of theory to fresh facts about *Man as he is*. And, meanwhile, the dreams and speculations of one thinker after another—even dreams and speculations which have moved nations and precipitated revolutions—have ceased to command men's reason, when they ceased to accord with their knowledge."

[55] p. iii.

[56] See *Dictionary of American Biography*. Greenwood wrote *An Experimental Course on Mechanical Philosophy* (1726), and *A New Method for Composing a Natural History of Meteors* (1728).

Winthrop also did much to popularize Newtonianism in America through his Harvard lectures.[57]

Fortunately, the history of the vogue in America of Newtonianism "as a model of government" has been traced by Professor Carl Becker,[58] and therefore it need not be repeated here. In summing up the pattern of ideas in vogue just before the Declaration of Independence, Mr. Becker shows that most people believed that: "There is a 'natural order' of things in the world, cleverly and expertly designed by God for the guidance of mankind; that the 'laws' of the natural order may be discovered by human reason; that these laws so discovered furnish a reliable and immutable standard for testing the ideas, the conduct, and the institutions of men—these were the accepted premises, the preconceptions, of most eighteenth century thinking, not only in America, but also in England and France." (p. 26). (If some of these ideas appear in Cicero, it must be remembered that, as we have already seen, many of the deists cited Cicero to reinforce their Newtonian ideas of law and order.) These views had been popularized in America by the Puritan pulpit, by libraries, almanacs, magazines, newspapers, schools, lectures, and by correspondence and the inter-relations of travelers in both countries.[59] I trust sufficient attention has been given to the fact that Puritanism helped in some ways to pave the way for political liberalism and for respect for science, and the fact that the transition from Puritanism to the Enlightenment was very gradual. It should be noted, however, that even such an ardent apologist for the Puritans as H. M. Jones admits that "the universe of the transcendentalist differs *toto caelo* from the Newtonian world-machine; and the deistic view of human nature contradicts at every turn that of high Calvinism."[59a]

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[57] See F. E. Brasch, "Newton's First Critical Disciple in the American Colonies—John Winthrop," in *Sir Isaac Newton, 1727-1927* (Baltimore, 1928), pp. 301-38; and also Brasch, "The Newtonian Epoch in the American Colonies," *American Antiquarian Society Proceedings*, N.S., XLIX, Oct. 1939, pp. 314-322.

[58] *The Declaration of Independence*, New York, 1922, Chapter II.

[59] See Alice Baldwin, *The New England Clergy and the American Revolution*, Durham, N.C. 1928; and H. M. Morais, *Deism in Eighteenth Century America*, New York, 1934, p. 55, where early libraries possessing Newton's works are listed.

[59a] *Authority and the Individual* (Cambridge, Mass.), p. 332 (in H. M. Jones' "The Drift to Liberalism in the American Eighteenth Century"). It is significant that leaders of liberalism in politics such as Jefferson and Paine had a fiery contempt for Puritanism and its belief in total

The new trend appears especially in the emphasis upon nature over the Bible as a *primary* guide to conduct, upon reason and science over the "religious affections" (the heart) as stressed by such Puritans as Edwards, and upon faith that the masses were sufficiently altruistic to be entrusted with their own government.

The close relation in this cosmopolitan age not only between contemporary English and American thought and thinkers, but also between scientific and political ideas, may be illustrated by the English Joseph Priestley, who came to America in 1794, although he had long been widely popular here. Indeed, Professor Lois Whitney, whose interpretation I follow, regards him as "representative of the progressivists"[60] in general and "a kind of touchstone" for their doctrines. Building upon the semi-Lockean theory of the "association of ideas" of the medical practitioner David Hartley, whose *Observations on Man* (1749) paved the way for later psycho-physiological doctrines, Priestley also accepted and elaborated some of the American Franklin's theories of the constitution of matter (in relation to its being penetrable by subtle electrical fluid)[61] and proceeded in his *Disquisitions Relating Matter and Spirit* (1777) to turn from the older dualism between them, to question a belief in the soul, and to correlate mind and body. Thus to Priestley all life became *one*, under the influence of science, especially chemistry, in which he was an almost unrivalled pioneer; it was thus natural that he should as an inductive scientist attack *a priori* theories about politics. "Human nature, with the various interests and connexions of men in a state of society, is so complex a subject that nothing can be safely concluded *a priori* with respect to it. Everything that we can depend upon must be derived from *facts*."[62] In Priestley's emphasis on political empiricism, "utility" and the "public good" he was not only in line with the British Bentham (who acknowledged him as the source of his criterion of "the greatest happiness of the greatest num-

depravity and the "elect," especially as these doctrines were translated into anti-equalitarian and aristocratic political practise. See Jefferson's *Writings*, Memorial Edition, XV, 384, 425, 403; VII, 252.

[60] Lois Whitney, *Primitivism and the Idea of Progress* (Baltimore, 1934), pp. 177ff.

[61] See Priestley's *History of Electricity*.

[62] *Lectures on History* (London, 1788), pp. 12-13.

ber")[63] but he was also in accord with Americans such as his friends Jefferson and Paine. In the rationalistic Priestley's attack on Burke's hostile *Reflections on the French Revolution,* he concluded, "To make the public good the standard of right or wrong, in whatever relates to society and government, besides being the most natural and rational of all rules, has the farther recommendation of being the easiest of application. Either what *God has ordained,* or what *antiquity* authorizes, may be difficult to ascertain; but what regulation is more conducive to the *public* good, though not always without its difficulties, yet in general it is much more easy to determine."[64] In his influential and early *First Principles of Government* (1768), he had already said: "The good and happiness of the members, that is, the majority of the members, of any state, is the great standard by which everything relating to that state must be determined." No wonder he was devoted to the principles of the American and the French revolutionists as being "glorious" and the "reverse of all the past"![65] No wonder the French made him an honorary member of their Convention, and no wonder, when his home and scientific laboratory was burned by a mob opposed to the French Revolution, he was widely welcomed by American liberals when he came here in 1794, as Jefferson said, to seek refuge in a land of free thought. Trained in science, one of the founders of Unitarianism in his attack upon *The Corruptions of Christianity* (1769), it was logical that he should have held that government should leave "all men the enjoyment of as many of their natural rights as possible, . . . no more interfering with matters of religion, with men's notions concerning God and a future state, than with philosophy or medicine."[66] Priestley was an ardent necessitarian who saw mind as a mechanism, the product of "cause and effect" which rules "as much in the intellectual, as in the natural world."[67] In his *Disquisitions Relating Matter and*

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[63] For details see Oliver Elton, *A Survey of English Literature, 1780-1880* (New York, 1920), I. 441-42.

[64] *Letters to the Right Honorable Burke,* second edition, Birmingham, 1791, p. 23.

[65] *Ibid.,* p. 145.

[66] Priestley's *Works,* ed. Rutt (1817-32), XXII, 236. His friend Richard Price, in his *Evidence for a Future Period of Improvement* (1787), based his hopes of progress in part upon "the diffusion of knowledge created by printing and better navigation" (p. 25). Price was also immensely popular in America.

[67] Priestley's *Doctrine of Philosophical Necessity* (London, 1777), p. xxx.

*Spirit,* he said that "the principle object is, to prove the uniform composition of man, or what is called *mind,* or the principle of perception and thought, is not a substance distinct from the body, but the result of corporeal organization."[68] Thus man and his controlling ideas can be changed by external influences, such as education and government. Like Franklin, Jefferson, and Paine, Priestley had little sympathy with the attempt to retain primitive conditions, but believed in building on nature by means of the art of education and the communication of ideas. Thus he says that "by *art* we not only anticipate the course of *nature,* but may communicate knowledge in an easier, because a more *regular* method than nature employs. . . . Indeed, without these advantages, no man, in this advanced age of the world, could possibly attain" to that condition in which, "the whole human species put in a progressive state, one generation advanc[es] upon another, in a manner that no bounds can be set to progress." Like Franklin, his friend Priestley held that "this progress is not *equable,* but *accelerated,* every new improvement opening the way to many others. . . ."[69] Second only to education, the communication of ideas, as the basis of progress, is the division of labor which promotes specialization and hence solidarity of group-interests; this is to be brought about not by a return to primitivism but by the development of society and government. "The great instrument in the hand of divine providence, of this progress of the species towards perfection, is *society,* and consequently *government.* In a state of nature . . . from generation to generation every man does the same that every other does, or has done; and no person begins where another ends. . . . This we see exemplified in all barbarian nations . . . where the connections of the people are slight, and consequently society and government very imperfect. . . . Whereas a state of more perfect society admits of a proper distribution and division of the objects of human attention. In such a state men are connected and subservient to one another; so that, while one man confines himself to one single object, another may give the same undivided attention to another object. Thus the powers of all have their full effect: and hence arise improvements

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[68] *Op. cit.*, p. 355.

[69] *Miscellaneous Observations Relating to Education* (Bath, 1778), pp. 2-4.

in all the conveniences of life, and in every branch of knowledge."[70] Like Jefferson, Priestley urges us to "give full scope to everything which may bid fair for introducing more variety among us. . . . It is only the education which men give them [inferior species] that raises any of them above the others. But it is the glory of human nature, that the operations of reason, though variable, and by no means infallible, are capable of infinite improvement."[71]

In considering Priestley's vogue in America, it must be remembered that his "system was carried from Pennsylvania (where he settled and lived from 1794 to 1804)[72] into the South by his son-in-law, Thomas Cooper," who had an even "wider knowledge of the literature of materialism" and who stated in a more balanced and persuasive form his own *Metaphysical and Physiological Arguments in Favor of Materialism.*[73] Although Cooper much later favored the southern secessionists, he was originally a ardent political liberal, attacking Burke, exalting Paine and the principles of the French Revolution.

While Franklin's early birth in Cotton Mather's Puritan Boston helped to give him more of a Puritan and conservative "hang-over" than had most of the men we are considering, it is important to notice that, being a "thorough deist" in religion, many of his most forward-looking political ideas derived from the natural-rights tradition. An authority on *Franklin's Political Theories* concludes that "most of Franklin's political ideas may be found in the writings of Locke,"[74] one of the founders of the science of psychology, with whom he was early familiar.[75] Thus "all the Property that is necessary to a Man, for the Conservation of the Individual and the Propagation of the Species, is his natural Right, which none can justly deprive him of. . . ."[76] Not only is property to Franklin a natural right, but

[70] *An Essay on the First Principles of Government* (London, 1768), pp. 4-7.

[71] *Ibid.*, pp. 78-80.

[72] For full details see Edgar F. Smith's *Priestley in America* (Phila., 1920). This book is devoted mainly to his contributions to science and written for "all those who are interested in the growth and development of science in this country." (Preface).

[73] See I. W. Riley, *American Thought* (New York, 1915), p. 102. Riley's *American Philosophy. The Early Schools* (New York, 1907), pp. 396-406 and *passim* provides elaborate analysis of Priestley's ideas.

[74] Malcolm R. Eiselen, *Franklin's Political Theories* (New York, 1928), p. 5.

[75] See Franklin's *Writings*, I, 243; II, 387n; III, 28.

[76] *Ibid.*, IX, 138. In this passage he goes on to defend the right of the state to tax property "superfluous to such purposes," whose value derives partly from the community at large.

civil liberty is to him "that heavenly Blessing, without which Mankind lose half their Dignity and Value."[77] While he always insisted upon the need for the self-reform of the individual, he also had faith in the people to direct their own government: "The People seldom continue long in the wrong, when it is nobody's Interest to mislead them."[78] Like the expositor of the *tabula rasa* environmental psychology, Franklin held that "our Opinions are not in our own Power; they are form'd and govern'd much by Circumstances."[79] He concerned himself, then, with improving our "circumstances," and with applying his Yankee reason to scientific inventions which would improve our physical welfare as a means to higher ends. He has been impressed, he said with "the growing felicity of mankind, from the improvements in philosophy, morals, and politics, and even the conveniences of common living, by the invention and acquisition of new and useful utensils and instruments. . . . For invention and improvement is rapid. . . . If the art of physic shall be improved in proportion with other arts, we may then be able to avoid diseases. . . ."[80] In political and economic matters, being a friend of the French physiocrats and of Adam Smith, Franklin regarded the order of nature as the order of God and he warned his readers against amending "the scheme of Providence . . . to interfere with the government of the world."[81] As opposed to mercantilists and those who would set up artificial barriers to trade between nations, Franklin said "In time perhaps Mankind may be wise enough to let Trade take its own Course, find its own Channels, and regulate its own Proportions."[82] Not only did he justify *laissez-faire* on the basis of natural laws (to the discovery of which science was devoted) but he thought as a deist that America's distinctive wealth, deriving from agriculture and fisheries, came directly from God.[83] Of all the ways of gaining wealth, "the only honest way," according to the "thorough deist," was that "wherein man receives a real increase of

[77] Quoted by Eiselen, *op. cit.*, p. 11.

[78] *Writings*, ed. Smyth, V, 461.

[79] Franklin's *Writings*, ed. Smyth, IX, 252.

[80] *Franklin*, ed. Mott and Jorgenson, p. 496 (to Rev. John Lathrop, May 31, 1788).

[81] Franklin's *Writings*, ed. Smyth, III, 135.

[82] *Ibid.*, IV, 243-44. For further evidence of his ardent espousal of a *laissez-faire* policy, see V. 534-39; VII, 176; II, 313-4; VIII, 260-1; IX, 63.

[83] Franklin's *Writings*, ed. Smyth, X, 122.

the seed thrown into the ground, in a kind of continual miracle, wrought by the hand of God in his favour, as a reward for his innocent life and his virtuous industry."[84] It should be evident, then, that his ardent agrarianism and his devotion to furthering the settlement of the western lands[85] was not unconnected with religious motivations, with his basic deism which rested, as we have seen, in no small measure upon science. As an apostle of The Enlightenment, Franklin thought that America's progress would be in line with the general beneficent tendency of Providence and that nationalisms would eventually blend into the good of all. ". . . our Revolution," he wrote his friend Richard Price, "is an important Event for the Advantage of Mankind in general. It is to be hoped that the Lights we enjoy, which the ancient Governments in their first Establishment could not have, may preserve us from their Errors."[86] Elsewhere he said that "our Cause is the Cause of all Mankind, and that we are fighting for their Liberty in defending our own. 'Tis a glorious task assign'd us by Providence. . . ."[87] He "sees the welfare of the parts in the prosperity of the whole" world, and he came to favor a league of nations to preserve peace.[88]

At first glance it seems odd that while Franklin was the most illustrious technical scientist of his contemporaries, his political theories appear to be less explicitly scientific than those of, say, Paine or Jefferson. Perhaps this fact is explained in part because, like his friend Priestley, he is an inductive and not a deductive scientist: and thus in avoiding *a priori* absolutes and proceeding as an empiricist step by step as political circum-

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[84] *Franklin*, ed. Mott and Jorgenson, p. 347 (in "Positions to be Examined, concerning National Wealth"). For Franklin's great and widely influential interest in agriculture from a scientific angle see the able study by E. D. Ross, "Benjamin Franklin as an Eighteenth-Century Agriculture Leader," *Journal of Political Economy*, XXXVII, 52-72 (Feb. 1929). For Franklin's economic theories see L. J. Carey, *Franklin's Economic Views* (New York, 1928)—a substantial book—and W. A. Wetzel, *Benjamin Franklin as an Economist* (Johns Hopkins University Studies in Historical and Political Science, 13th series, IX, 421-76. Baltimore, 1895.) The interesting manner in which many of his economic interests were deduced from science and deism is demonstrated by Mott and Jorgenson, *op. cit.*, pp. lxiv-lxxxi.

[85] Franklin's *Writings*, ed. Smyth, III, 358-66 ("Plan for Settling Two Western Colonies"); IV, 461-2; V, 314; V, 465-527.

[86] *Ibid.*, IX, 256.

[87] *Ibid.*, VII, 56. See also VI, 311, on his view of "the glorious public virtue so predominant in our rising Country" in contrast to "the extream Corruption" of Europe. Also VI, 409; IX, 87-8; on his faith in America's development as part of a new world-order of increased happiness for all, see VI, 93; VII, 56; IX, 256; III, 339; IV, 4; V, 21; VI, 322.

[88] *Ibid.*, V, 155-56; IX, 107; VIII, 80-82, 207, 263; IX, 3-7, 291-9; IX, 657.

stances warrant, Franklin is really paralleling, at least, his procedure as a scientist. His criterion, like Priestley's, is practical utility. On one occasion, for example, he renounced a doctrine which, "tho' it might be true, was not very useful."[89]

While Franklin may have been deficient in an historical imagination, he was surely pre-eminent as regards what one might call a mathematical and social or humanitarian imagination. Deism having led him to discount prayer and to believe that the "most acceptable service of God was doing good"[90] in some practical way so as to lessen external causes of misery, Franklin is often amazing in the fertility of imagination which leads him not only to all sorts of scientific inventions (such as Franklin stoves, bifocal spectacles) and social plans (such as fire insurance, circulating libraries, etc.) but also to the convincing demonstration of the cumulative value of trifles—witness his mathematical proof of the fruits of thriftiness.

Jefferson followed Franklin as our representative in France; and in his *Notes on Virginia* (1784),[91] written to refute the French Buffon's view that animal life degenerated in America, Jefferson paid high tribute to Franklin's achievements as a scientist. While in France, as well as in his earlier and later reading, he acquainted himself with the pattern of ideas of the Encyclopedists and heralds of the French Revolution, including his friend Condorcet. "Broadly stated," says John Morley of this school of thought, "the great central moral of it all was this: that human nature is good, that the world is capable of being made a desirable abiding place, and that the evil of the world is the fruit of bad education and bad institutions."[92] Long before going to France, however, Jefferson had been influenced by scientific ideas at the College of William and Mary. "Placed alongside Newton," he said, "every human character must appear diminutive."[93] He read so widely that it is difficult to evaluate the influence of all the ideas to which he was exposed, but it is significant that he regarded the scientists

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[89] *Franklin*, ed. Mott and Jorgenson, p. 55.

[90] *Ibid.*, 69.

[91] For this work Jefferson assembled a mass of scientific data to prove that plants, animals, and even men thrived better in the American environment than they did in that of Europe.

[92] John Morley, *Diderot and the Encyclopedists* (London, 1880), p. 4.

[93] Jefferson's *Writings* (Memorial Edition), XIV, 79.

"Bacon, Newton, and Locke" as the "trinity of the three greatest men the world has ever produced."[94] We may be justified, then, in supposing that he was influenced by the Baconian inductive method as it ran counter to the acceptance of mere authority; by the Newtonian doctrine of the immutability of natural law as a divine revelation; and by the Lockean doctrine of *tabula rasa* and hence the idea that man is a product of environment as well as the doctrine that government should rest on a revocable social contract. Riley claims that he knew the doctrines of Erasmus Darwin, the grandfather of the evolutionist, and that his views of natural history fixed the destinies of his life.[95] He was also considerably influenced by the scientific materialism of his friends Joseph Priestley and Thomas Cooper.[96] And he admitted that he professed the same political principles as those of Thomas Paine, whose doctrines rested to a considerable extent upon Newtonian analogies.

It will be recalled that Jefferson said that in the natural-rights doctrine and the appeal to "the laws of nature and of nature's God" in the Declaration of Independence he expressed simply "the sentiments of the day" and that Carl Becker has shown that these were closely associated with Newtonianism, especially as interpreted by its popularizers. "Even in Europe," he says, "a change has sensibly taken place in the mind of man. Science has liberated the ideas of those who read and reflect, and the American example had kindled feelings of right in the people. An insurrection has consequently begun, of science, of

[94] *Best Letters*, p. 162. Jefferson was strongly influenced in his youth by Dr. Small and Governor Fauquier, a Fellow of the Royal Society, whose father had worked with Newton. See Chinard, *Jefferson*, 1929, p. 12. On Locke's vast influence both as psychologist and political thinker, see Kenneth MacLean's inadequate *Locke and English Literature of the Eighteenth Century* (New Haven, 1936), P. E. Aldrich, "John Locke and the Influence of his Works in America," Publications of the American Antiquarian Society, April, 1879, pp. 22-39, dealing mainly with the use of Locke's works as textbooks in American Schools and colleges; and especially Merle Curti's "The Great Mr. Locke, America's Philosopher, 1783-1861," *The Huntington Library Bulletin*, Vol. II, pp. 107-151, (April, 1937). It should be remembered that the doctrines of the rationalist Locke were disseminated by the Puritan clergy with great effect. See C. H. Van Tyne, "The Influence of the Clergy . . . in the American Revolution," *American Historical Review*, XIX, 44-64. Van Tyne finds the doctrines so disseminated more influential than the economic causes of the War.

[95] See I. W. Riley, *American Philosophy*, p. 267, who cites Lyon G. Tyler's *Early Courses and Professors at William and Mary College*, 1904, pp. 5-6. See Riley's whole excellent chapter on Jefferson's thought, pp. 266-295. Also T. C. Johnson's *Scientific Interests in the Old South* (New York, 1936).

[96] Riley, *passim*.

talents, and courage, against rank and birth, which have fallen into contempt. . . . Science is progressive, and talents and enterprise on the alert." He regarded freedom as "the first born daughter of science"[97] and the advance in science, he says repeatedly, is the basis of his contempt for the guidance of the past and his faith in progress. "One of the great questions, you know," he wrote John Adams in 1813, "on which our parties took different sides, was on the improvability of the human mind in science, in ethics, in government, etc. Those who advocated reform of institutions, *pari passu*, with the progress of science, maintained that no definite limits could be assigned to that progress."[98]

Those who believed that Jefferson was naive and gullible in trusting the people with their own government, who imagined that he stood for a kind of *a priori* acceptance of universal "natural goodness" of men, neglected the three-fold scientific basis for his faith in the people. In the first place, he insists that the people can be trusted with a democratic government only in so far as opinions may be freely debated and communicated, and provision is made for universal education grounded upon science.[99] (Discussion of this topic will be reserved for our later section on Education.) In the second place, in accord with the environmentalism[100] which stems from the *tabula rasa* doctrine

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[97] *Writings*, ed. Ford, VII, 3. [See Lucy M. Gidney, *L'Influence des Etats-Unis d'Amerique sur Brissot, Condorcet, et Mme. Roland* (Paris, 1930)].

[98] *Ibid.*, IX, 387. See also the Memorial Edition, XV, 399. Occasionally he had misgivings that "morals do not necessarily advance hand in hand with the sciences," especially in time of war, but in general he was an ardent believer in progress to be effected by the education of the people in science. For exhaustive evidence see Edwin Martin's doctoral dissertation, *Jefferson and the Idea of Progress*, available in manuscript at the Library of the University of Wisconsin.

[99] For his belief that democracy depends upon free inquiry and education, see *Writings*, Memorial Edition, XII, 417 ("the information of the people at large can alone make them the safe, as they are the sole, depository of our political and religious freedom"); V, 396-7; II, 221-2; III, 319; XIV, 103; XII, 387; XV, 339; XI, 34; XIV, 245; II, 207; XV, 114; XIV, 245; XIII, 43.

[100] W. D. Wallis in his article on "Environmentalism" (*Encyclopedia of Social Sciences*, V, 561-66) defines it as "the tendency to stress the importance of physical, biological, psychological or cultural environment as a factor influencing the structure or behavior of animals, including man." He cites the origins I have indicated, including not only Locke but also Turgot, d'Holbach, and Condorcet, Jefferson's friend. American environmentalism may be illustrated from Crévecoeur's *Letters from an American Farmer* (Everyman ed. pp. 44-5): "Men are like plants; the goodness and flavour of the fruit proceeds from the peculiar soil and exposition in which they grow. We are nothing but what we derive from the air we breathe, the climate we inhabit, the government we obey, the system of religion we profess, and the nature of our employment." Transplanted from Europe to the frontier environment, "The American is a new man, who acts upon new principles."

of the psychologist Locke and which was elaborated upon by the French liberals devoted to science, Jefferson merely thought that for a limited period America's good fortune in having plenty of land and consequently a majority of farmers[101] who owned their means of getting a living would give Americans a sense of responsibility and a "stake in society" which would contribute to wise government. In the third place, following thinkers such as Locke and Priestley, Jefferson held that "opinions change with the change of circumstances," and hence "institutions must advance also, and keep pace with the times."[102] The present generation, he said in 1819, "are wiser than we were, and their successors will be wiser than they, from the progressive advance of science."[103] Thus Jefferson opposed any static kind of government, preferring to keep it flexible and responsive to changing human needs and new opportunities provided by the discoveries of science.[104]

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[101] "In Europe the lands are either cultivated, or locked up against the cultivator. Manufacture must therefore be resorted to of necessity not of choice, to support the surplus of their people. But we have an immensity of land courting the industry of the husbandman. . . . Those who labor in the earth are the chosen people of God, if ever He had a chosen people, whose breasts He has made His peculiar deposit for substantial and genuine virtue. It is the focus in which he keeps alive that Sacred fire, which otherwise might escape from the face of the earth. Corruption of morals in the mass of cultivators is a phenomenon of which no age nor nation has furnished an example. It is the mark set on those, who, not looking up to heaven, to their own soil and industry, as does the husbandman, for their subsistence, depend for it on casualties and caprice of customers. Dependence begets subservience and venality, suffocates the germ of virtue, and prepares fit tools for the designs of ambition. This, the natural progress and consequence of the arts, has sometimes perhaps been retarded by accidental circumstances; but, generally speaking, the proportion which the aggregate of the other classes of citizens bears in any State to that of its husbandmen, is the proportion of its unsound to its healthy parts, and is a good enough barometer whereby to measure its degree of corruption. While we have land to labor then, let us never wish to see our citizens occupied at a workbench, or twirling distaff." (Jefferson's *Writings*, Memorial Edition, II, 228-30). It should be noted with reference to this passage that his faith in agrarianism is associated with the deistic idea that since God created the land and its produce, he who tills it is closest to God. Elsewhere (Ford edition, IV, 479-80) he says, "I think our governments will remain virtuous for many centuries; as long as they are chiefly agricultural; and this will be as long as there shall be vacant lands in any part of America. When they [the people] get piled upon one another in large cities, as in Europe, they will become corrupt as in Europe." He elaborates the same idea in the Memorial Edition, XIII, 401, adding that among American farmers "everyone, by his property, or by his satisfactory situation, is interested in the support of law and order. And such men may safely and advantageously reserve to themselves a wholesome control over their public affairs, and a degree of freedom, which, in the hands of the *canaille* of the cities of Europe, would be instantly perverted to the demolition and destruction of everything public and private." For full analysis see Joseph Dorfman's "Economic Philosophy of Thomas Jefferson," *Political Science Quarterly*, LV, 98-121 (March, 1940).

[102] *Writings*, Memorial Edition, XV, 41. See also XIV, 491; XV, 325.

[103] R. J. Honeywell, *The Educational Work of Thomas Jefferson*, pp. 251-2, quotes similar passages and elaborates upon them, emphasizing the influence of science.

[104] On his insistence upon the need for constant, preferably peaceful, revolution and change in government see Memorial Edition, I, 139, 150; IX, 9-10; XIX, 268-9; XV, 300; VI, 372; IX,

Let us turn now to Jefferson's ablest lieutenant as a journalistic broadcaster of his doctrines, to Philip Freneau, who while employed in the office of the Secretary of State edited the *National Gazette* from 1791 to 1793, making it "the leading paper in America,"[105] in opposition to the Federalistic Fenno's *Gazette of the United States.* Except for an occasional yearning for primitivistic simplicity, as befits his poetic nature, Freneau may be said to have been in the main current of The Enlightenment and to have emphasized science (along with reason), in its broad phases, as the central basis of political freedom and progress. The development and logical articulation of his ideas are worth considering with some care. To Freneau all things in nature are

> "But thoughts on reason's scale combin'd,
> Ideas of the Almighty mind."[106]

Hence in discovering the immutable "general laws" by which nature operates, the scientist is essentially a holy man because he is thinking God's thoughts after him. God "lives in all" things, in "meaner works" as well as "in the starry sphere";[107] even the little plant

> "enjoys her little span—
> With *Reason* only less complete
> Than that which makes the boast of man."[108]

Freneau holds that "science . . . stands firm on Reason,"[109] and he constantly compares reason to a sun

> "whose unquenchable ray
> Progressive, has dawn'd on the night of the mind,
> From the source of all good. . . ."[110]

Hence, when free, human reason naturally gravitates toward

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336; VI, 25, 65, 372-3, 150-1; IX, 389. He thought that each generation has a right to modify the laws passed by their predecessors. " 'The earth belongs in usufruct to the living'; the dead have neither powers nor rights over it." (Ford edition, V, 116).

[105] G. H. Payne, *History of Journalism in the United States* (New York, 1920), p. 163. His ablest and latest biographer, Lewis Leary (*That Rascal Freneau,* New Brunswick, 1941, pp. 212-4. 389, 245, 208, 186-9, 259, 316) presents fresh evidence to show that Jefferson advised and influenced Freneau as editor.

[106] *Poems of Freneau,* ed. H. H. Clark (New York, 1928), p. 208.

[107] *Ibid.,* 422 ("On the Universality and Other Attributes of the God of Nature"). "All Nature forms on Reason's plan." *Ibid.,* 343.

[108] *Ibid.,* p. 378. It should be noted that this belief of the sentience of nature was expressed nine years *before The Lyrical Ballads* by Wordsworth and Coleridge.

[109] *Ibid.,* 416.

[110] *Poems of Philip Freneau,* ed. Pattee, Princeton, 1907, III, 299.

what is divinely good, to its source. In the confident faith of The Enlightenment Freneau attacks as "vile as vain" all "Abuse of Human Power as Exercised over Opinion":

> "No, leave the mind unchain'd and free,
> And what they ought, mankind will be,
>
> ................
>
> . . . Good and great, benign and just,[111]
> As God and nature made them first."

Thus a rational "Religion of Nature" inevitably

> "Inclines the tender mind to take
> The path of right, fair virtue's way
> Its own felicity to make."[112]

If in the light of scientific deism men are naturally good, what is the source of human misery and evil? He answers Kings and priests,—monarchy and an Established Church—"impoverish man" (who is naturally good when "left to himself") and "keep worlds at variance." [113]

And finally, in an essay in *The Time-Piece* (Sept. 8, 1797) Freneau outlines his views of human history and progress. "At first a mere barbarian," man "at length by thought and reason's aid" forsook his savage den and lived as "a mild, beneficent, humane creature, without wars, nor inclined to the shedding of blood. . . . This was the law of reason. It is by abandoning this great law, by disregarding the light within him, and by surrendering it to the will of others, that man has become what he is—a mean, base, cruel, and treacherous being. It is from false forms of government that the far greater part of human miseries and human vices are derived."[114] Then, continues Freneau's essay of Sept. 8, 1797, kings and priests having long perverted institutions to ignoble ends, philosophic reason came down from heaven to save mankind by persuasion rather than force. The despots redoubled their efforts and appeared to triumph for a time.

> "Yet, nature must her circle run—
> Can they arrest the rising sun?"

[111] *Poems of Freneau*, ed. Clark, p. 166.

[112] *Ibid.*, p. 424. See also p. 157 and p. 166 on natural goodness.

[113] *Ibid.*, pp. 155-157 ("Reflections on the Gradual Progress of Nations from Democratical States to Despotic Empires").

[114] The last quotation is from *The Time-Piece*, March 24, 1797.

Thus the poet sees current despotism—especially the opposition to the French Revolution, and the American Federalists—as representing merely a parenthesis or a detour in the history of progress.[115] It is significant that the democratic leaders he admires, who are to deliver us from bondage, are all devoted to reason and to science. Thus Franklin is the "prince of all philosophy" and his "fair science" makes him "the rival of Britannia's sage," Newton; Freneau sees "sweet liberty" and science "irretrievably" joined.[116] When the Federalists,

> "Domestic traitors, with exotic, join'd,
> To shackle this *last refuge* of mankind,"

the great Jefferson arose to reclaim our rights—Jefferson, who could

> "with Newton, . . . the heavens explore,
> And trace through nature the creating power."[117]

He rejoiced because the universe rings "with a code of new doctrines" and [Thomas] "Paine is addressing strange sermons to kings"[118] in *The Rights of Man.* Freneau wrote two poems in praise of Paine who held that science enables us to "see God, as it were, face to face" in nature; he rejoiced that "from Reason's source, a bold reform he brings," and "in raising up mankind, he pulls down kings" who had "Nature's law reversed."[119]

> "Peace to all feuds!—and come the happier day
> When Reason's sun shall light us on our way;
> When erring man shall all his Rights retrieve,
> No despots rule him, and no kings deceive."[120]

The solar system as interpreted by Newton is suggested as an ideal "model" of government operating by impartial laws and based on social harmony and natural goodness, as opposed to a system depending on the personal caprice of despots who ar-

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[115] Exhaustive evidence on this subject has been assembled and interpreted in a doctoral dissertation done under my direction by Macklin Thomas entitled *The Idea of Progress in Franklin, Barlow, Freneau, and Rush,* available in manuscript at the Library of the University of Wisconsin.

[116] *Poems of Freneau,* ed. Clark, pp. 12-13.

[117] *Ibid.,* 171-72.

[118] *Poems of Freneau,* ed. Clark, p. 109 (In the poem "To the Public" which sets the tone of the first number of *The National Gazette,* Oct. 31, 1791.

[119] *Ibid.,* 124-5.

[120] *Ibid.,* 112.

range so that "the few . . . possess all earthly good" while millions are "robbed":

"Great orb, that on our planet shines,
Whose power both light and heat combines,
    You should the model be;
To man, the pattern how to reign
With equal sway, and how maintain
    True human dignity.

Impartially to all below
The solar beams unstinted flow,
    On all is poured the Ray,
Which cheers, which warms, which clothes the ground
In robes of green, or breathes around
Life;—to enjoy the day."[121]

He would revive "laws," analagous to those divinely "designed" by the author of the solar system, to control the "love of wealth." Then

"Men will rise from what they are;
Sublimer, and superior far,
    Than Solon guessed, or Plato saw;
All will be just, all will be good—
Then harmony, 'not understood,'
    Will reign the general law."[122]

Dr. Benjamin Rush, himself both scientist and democrat, concluded in his eloquent *Eulogium* of the astronomer Rittenhouse, "How could he behold the beauty and harmony of the universe as a result of universal and mutual dependence, and not admit that Heaven intended Rulers to be dependent upon those, for whose benefit, alone, all government should exist? To suppose the contrary would be to deny unity and system on the plans of the great Creator of all things."[123] Rittenhouse[124] him-

[121] It is perhaps not entirely fanciful to trace part of Freneau's ardent agrarianism and his assertion of man's right to some land as a regenerative influence, to his deism.

[122] *Poems of Philip Freneau*, ed. Pattee, III, 222-3 ("On False Systems of Government, and the Generally Debased Condition of Mankind"). See also Freneau's *Poems*, Phila., 1809, I, 253-6 on Newtonianism as a model for government. Freneau's poem on "Science Favourable to Virtue" and especially philanthropy will be discussed under Humanitarianism later.

[123] William Barton, *Memoirs of the Life of David Rittenhouse*, 1813, p. 515.

[124] See also T. D. Cope, "David Rittenhouse—Physicist," *Journal of the Franklin Institute*, CCXV, 287-97 (March, 1933); M. J. Babb, "David Rittenhouse," University of Pennsylvania *University Lectures* 1914-1915, pp. 595-608.

self, a president of the American Philosophical Society, and an ardent republican, hopes (1775) that, if the other planets have inhabitants, "they are wise enough to govern themselves according to the dictates of that reason their creator has given them,"[125] and he proceeds to attack slavery, national rapacity, the scourges of war, and the inroads of luxury.

Most clearly of all, however, Thomas Paine demonstrates the manner in which science and scientific deism inspired republican doctrines. According to his testimony, for some time *after* having studied astronomy and come to doubt Christianity, he said, he "had no disposition for what are called politics. . . . When, therefore, I turned my thoughts towards matters of government, I had to form a system for myself, that accorded with the moral and philosophic principles in which I had been educated."[126] Clearly, then, his political theories grew out of his religion (which was based mainly on Newtonian science) and its moral and philosophic implications. He traces his central doctrine of the rights of man "to the time when man came from the hand of his Maker."[127] It is a *religious* doctrine. Then he sought to establish in civil society the reign not of capricious personality through feudal force but the reign of impersonal law and order comparable to the law and order of the Newtonian system. Paine was one of the earliest advocates of a Federal constitution. He deifies law.[128] Finally, he thought this reign of law could be effected best by a representative government rooted in the natural goodness of the people. Newtonian gravitation had taught him, as we have seen, that men are harmoniously drawn together by their needs. "The great mass of people are invariably just."[129] "Man, were he not corrupted by governments, is naturally the friend of man, and . . . human nature is not of itself vicious."[130] "The representative system is always parallel with the order and immutable laws of nature, and meets the reason of

[125] Barton, *op. cit.*, 566-68. Rittenhouse's advanced radicalism is suggested by the fact that he was one of the "very few" to whom Thomas Paine dared to show his *Common Sense* (Jan. 10, 1776) while it was in manuscript. Paine characterizes Rittenhouse as "of known Independent Principles" (*Writings of Thomas Paine*, I, 135).

[126] *Writings*, IV, 62-63.

[127] *Ibid.*, II, 303. For further discussion, see my Introduction to *Thomas Paine* (1944) in the "American Writers Series."

[128] *Ibid.*, I, 340; III, 277; I, 99.

[129] *Ibid.*, III, 122.

[130] *Ibid.*, II, 453.

man in every part";[131] such being "the order of nature, the order of government must necessarily follow it,"[132] for "all the great laws of society are laws of nature,"[133] discovered by science.[134] The appeal to natural law in matters of social justice, has, of course, an ancient and honourable history.[135] Witness its appearance in such Greek works as *Antigone*, and its wide use in Roman jurisprudence. The ancient doctrine was powerfully reinforced, however, by the reasoning made possible by scientific proof of a physical universe of harmonized and divinely ordained laws, immutable, universal, and beneficent, and this proof was provided by Newton, the scientist, and popularized by scientific deists.

The political implications of scientific ideas appear perhaps most glamorously in the work of Joel Barlow, the "intimate friend"[136] of Thomas Paine, whom he praised as "a luminary of

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[131] *Ibid.*, II, 426.

[132] *Ibid.*, II, 419.

[133] *Ibid.*, II, 408.

[134] Elihu Palmer, who regarded Paine as "probably the most useful man that ever existed," (*Principles of Nature*, 3rd ed., N.Y. 1806, p. 112), gave the ideas here discussed wide publicity and tried to organize deism as a church. His reliance on science as producing a "new era in the intellectual history of man" should be clear in the following sentences: "Newton, profiting by the errors of those great philosophers, Descartes and Bacon; . . . developed with clearness the physical principles and order of the planetary system, and struck with everlasting death and eternal silence the theological pretension of all former ages. . . . It was not the discovery of physical truths alone that bore relation to the renovation of the human species; it was reserved for Locke, and other powerful minds, to unfold the eternal structure of the intellectual world; explain the operation of the human understanding; explore the sources of thought, and unite sensation and intellect in the same subject, and in a manner cognizable by the human faculties. Locke has, perhaps, done more than Newton, to subvert the credit of *divine Revelation*; but neither of them discovered the extent of the doctrines upon the moral interests of man. Sensation being established as the source and cause of all human ideas, a system of true and material philosophy necessarily followed. . . . Mirabaud [Holbach], Rousseau, Voltaire, Hume, and Bolingbroke, together with twenty other philosophers of France and England, combined their strength in the philanthropic cause of human improvement. . . ." (*Ibid.*, pp. 110-112). Let "Reason, righteous and immortal reason, with the argument of the printing types in one hand, and the keen argument of the sword in the other, . . . attack the thrones and hierarchies of the world, and level them with the dust; then the emancipated slave must be raised by the power of science into the character of an enlightened citizen. . . . (*Ibid.*, 123-24). "Human science is extending itself into every part of the world; it has already revived the hopes of one third of the human race, and its character bears a most indubitable relation to the emancipation of the whole. . . . And to this source of human improvement no limits can be assigned—it is indefinite and incalculable; and its moral, philosophical, and political effects upon intelligent life, will one day strike with horror the oppressors of the human race." (*The Political Happiness of Nations*, N.Y., 1800, pp.15-16).

[135] See surveys by C. G. Haines, *Revival of Natural Law Concepts*, Cambridge, Mass., 1930, Chapter I, "Ancient and Mediaeval Natural Law Doctrines"; Otto Gierke, *Natural Law and the Theory of Society, 1500 to 1800*. Translated by E. Barker. 2 vols. Cambridge, England, 1934; B. F. Wright, *American Interpretations of Natural Law*, Cambridge, Mass., 1931; C. F. Mullett, *Fundamental Law and the American Revolution, 1760-1776*. New York, 1933.

[136] Rickman's *Life of Thomas Paine* (London, 1819), p.132.

the age, and one of the greatest benefactors of mankind."[137] Even in Barlow's early *Vision of Judgment* a tribute to science as leading to true religion and progress occupies the climax of the poem: "fair science, of celestial birth . . . leads mankind to reason and to God";[138] inspired by science, man must

> "Look through earth and meditate the skies,
> And find some general laws in every breast,
> Where ethics, faith, and politics may rest."[139]
>
> "Equality of Right is nature's plan;
> And following nature is the march of man."[140]

It is significant that while Barlow's Part I of *Advice to the Privileged Orders* is dedicated to France's King Louis XVI (as the supposed friend of reform, to be sure), Part II is dedicated to the scientist and inventor of the steamboat, Robert Fulton, who also inspired Barlow's *The Canal,* whose subtitle reads "A Poem on the Application of Physical Science to Political Economy" (1802). The opening lines say that he wishes

> "To teach from theory, from practise show
> The Powers of State, that 'tis no harm to know
> And prove how Science, with these powers combined,
> May raise, improve, and harmonize mankind."[141]

The re-working of *The Vision of Columbus* in *The Columbiad* of 1807 shows that Barlow has become a whole-hearted disciple of The Enlightenment. In the view of the future at the end of the latter poem science is the basic agent in social progress. Inland waterways, canals, irrigation, and draining will make it possible to feed more people. Science will help to eliminate disease, the

[137] Barlow's *Advice to the Privileged Orders,* edition of 1795, Part II, pp.5-6. He says he was relieved of further analysis of the subject of Revenue and Expenditure by the appearance of *Rights of Man,* Part II. It is generally admitted that Barlow was greatly indebted to Paine's *Rights of Man.* On the other hand, Barlow's earlier *Vision of Judgment* (1787) may have influenced Paine, for we find him listed among the "Subscribers" to it.

[138] *Vision of Columbus,* edition of 1787, p.217.

[139] *Ibid.,* 229. See also p. 235 where the "lights of science" will "sense with reason blend" and "view the great source of love" in heaven.

[140] *The Connecticut Wits,* ed. Parrington, p. 350. In his *Letter . . . to . . . Piedmont, on the Advantages of the French Revolution* (London, 1795) he said, "as long as we follow nature, in politics as well as morals, we are sure to be in the right."

[141] The poem, available in the Pequot Library in manuscript, is unpublished; I quote the lines from M. R. Adams' "Joel Barlow, Political Romanticist," *American Literature,* IX, 113-153 (May, 1937), pp. 140-41.

length of life will be greatly increased, chemistry will work wonders, engineers will control the storms, men will ride the air and go under the ocean, and physical science will flower in a new moral science which, by developing commerce, will lead to enduring world peace. And this will be insured and crowned by "a general congress of all nations, assembled to establish the political harmony of mankind,"[142] analagous to the harmony of the Newtonian universe.

## III

### HUMANITARIANISM

In approaching the vogue of social reform in the late eighteenth century among Americans, one must consider not only ideas but external circumstances. Thus harshly restrictive governmental acts enforced by the British on the eve of the Revolution and wide-spread social suffering in connection with the birth of the nation and the demands of a frontier environment naturally made people especially attentive to any proposals which promised a better[143] social order and greater happiness for the common man. Increased interest in humanitarian activi-

[142] See the summary "Argument" of the *Columbiad*, Book X. In a doctoral dissertation, which I directed, by Macklin Thomas on *The Idea of Progress in the Writings of Franklin, Freneau, Barlow, and Rush* it is concluded (*Summaries of Doctoral Dissertations*, University of Wisconsin, Vol. III, 1938, p. 310) that "Barlow, like Fieneau, identifies universal and human progress, thinking of progress as the gradual emergence of the perfect order of nature on the temporal plane. He defines the natural social state, however, as a complex civilization [like Priestley], and rejects the goodness of primitive society. He discovers the certainty of progress in the movements of enlightenment and republican government, both of which contain principles of necessary growth. Society will perfect itself by means of science, education, and democracy working interdependently." On Barlow's growing liberalism and increasing faith in science see Percy Boynton's "Joel Barlow Advises the Privileged," *New England Quarterly*, XII, 477-499 (Sept., 1939).

[143] See A. Nevins, *The American States . . .* 1775-1789, New York, 1927, Chapter X, "Progress in Liberalism and Humanity," p. 420-69, and long bibliography, p. 688. Also the chapter on "progress" in Sidney L. Pomerantz's *New York, An American City*, 1783-1803, New York, 1938. . . . See also the studies (*post*, notes 148, 151) dealing with the vast interest of Franklin and Jefferson in humanitarian projects. See also Robert J. Hunter, "The Activities of the Members of the American Philosophical Society in the Early History of the Philadelphia Almshouse," *Proc. Am. Phil. Soc.*, LXXI, 309-319 (1932); and "The Origin of the Philadelphia General Hospital," *Penna. Mag. Hist. and Biol.*, LVII, 32-57; M. A. DeWolfe Howe, *The Humane Society of Massachusetts*, 1785-1916; E. L. Pennington's "The Work of the Bray Associates in Pennsylvania," *Penna. Mag. Hist. and Biol.*, LVIII, 1-25 (Jan. 1934), includes evidence of Franklin's humanitarianism interest in negro education.

ties owed much to a variety of influences[144] such as the general tradition of Christian charity, the rise of Quakerism and Methodism, the rise of sentimentalism, and the example of English philanthropists, abolitionists, and prison-reformers such as Howard and Wilberforce.

Humanitarianism, however, owes more to rationalism (enlightenment), scientific deism, and the practical application of science to inventions than has been generally recognized. The conservative Presbyterian, Samuel Miller, summed up the basic assumption of the liberals at the end of the eighteenth century as follows: "in short, in the estimation of those who adopt this doctrine [of progress and liberalism], man is the child of circumstances; and by meliorating these, without the aid of [orthodox] religion, his true and highest elevation is to be obtained; and they even go so far as to believe that, by means of the advancement of light and knowledge, all vice, misery and death may finally be banished from the earth."[145]

If men are naturally good and self-love and social are the same, and evil derives from the outward environment, then it followed, the more advanced deists thought, that evil and suffering may be remedied by changing the environment either through rational legislation, education,[146] or by the scientific improvement of physical conditions. Evil being of outward origin, self-conquest should be subordinated to institutional reforms. As Paine said, "prayer is futile, since God cannot interfere with the immutable laws of the world-machine." Franklin was no doubt inspired partly, as he admitted, by Cotton Mather's *Essays to Do Good,* but it was after he became a "thorough Deist" that he elaborated his creed according to which "the most acceptable service of God was the doing good to man."[147] It is true that

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[144] See John Lathrop, *Discourse before the Humane Society in Boston* (Boston, 1787); also B. K. Gray, *A History of English Philanthropy*; Michael Kraus, "Eighteenth Century Humanitarianism: Collaboration between Europe and America," *Penna. Mag. of Hist. and Biog.*, LX, 270-286 (July, 1936), and "Slavery Reform in the Eighteenth Century: an Aspect of Trans-atlantic Cooperation," *ibid.*, LX, 53-66 (Jan., 1936); Ernest Caulfield, *The Infant Welfare Movement in the 18th Century* (New York, 1931); E. M. North, *Early Methodist Philanthropy*; and also, Sterling Johnson's unpublished John Hopkins' dissertation, *Historical Inter-relations between the English and American Humanitarian Movements*.

[145] Samuel Miller, *Retrospect of the Eighteenth Century*, New York, 1803, II, 295.

[146] Jefferson wrote from Paris on Aug. 13, 1786, to his friend George Wythe that aristocracy and churchcraft "alone" loaded Europeans with "misery," and that the "diffusion of knowledge among the people" was America's main basis for hoping for a better social order. "I think," he

Franklin was a utilitarian, but this interest was inspired by his scientific deism, which would appear to have directed his multitudinous services in the matter of hospitals, schools, libraries, stoves, street-lights, street-cleaning, etc., and his many inventions. He was one of the advocates of the abolition of slavery. His use of science as a means of saving time and health and life has been the subject of a score of monographs.[148] Franklin's more radical disciple, Thomas Paine, who insisted that his basic doctrines derived from Newtonian astronomy, held that "the only way of serving God is that of endeavoring to make his creation happy."[149] As a scientist Paine invented a crane,

wrote, "by far the most important bill in our whole code is that for the diffusion of knowledge among the people. No other sure foundation can be devised, for the preservation of freedom and happiness. If anybody thinks that kings, nobles, or priests are good conservators of the public happiness, send them here. It is the best school in the universe to cure them of that folly. They will see here, with their own eyes, that these descriptions of men are an abandoned confederacy against the happiness of the mass of the people. The omnipotence of their effect cannot be better proved than in this country particularly, where, notwithstanding the finest soil upon earth, the finest climate under heaven, and a people of the most benevolent, the most gay and amiable character of which the human form is susceptible; where such a people, I say, surrounded by so many blessings from nature, are yet loaded with misery, by kings, nobles, and priests, and by them alone. Preach, my dear Sir, a crusade against ignorance; establish and improve the law for educating the common people. Let our countrymen know that the people alone can protect us against these evils, and that the tax which will be paid for this purpose is not more than the thousandth part of what will be paid to kings, priests, and nobles, who will rise up among us if we leave the people in ignorance. The people of England, I think, are less oppressed than here. But it needs but half an eye to see, when among them, that the foundation is laid in their dispositions for the establishment of a despotism. Nobility, wealth, and pomp are the objects of their adoration. They are by no means the free-minded people we suppose them in America. Their learned men, too, are few in number, and are less learned, and infinitely less emancipated from prejudice, than those of this country." (F. C. Prescott, ed., *Hamilton and Jefferson*, New York, 1934, p. 257-8.).

[147] *Franklin*, ed. Mott-Jorgenson, p. 69.

[148] On Franklin's interests in science and scientific inventions see, in addition to the general studies already cited (such as Mott-Jorgenson, Bruce [*Franklin Self Revealed*, II, 350-422], Faÿ, and Smyth): Brother Potamian and J. J. Walsh, *Makers of Electricity*, New York, 1909, pp. 68-132; John Trowbridge, "Franklin as a Scientist," Publ. Col. Soc. Mass., XVIII, (1917); E. J. Houston, "Franklin as a Man of Science and as an Inventor," *Journal of Franklin Institute*, CLXI, 241-383 (April-May, 1906); "Franklin's Place in the Science of the Last Century," *Harper's Mag.*, LXI, 265-75 (July, 1880); O. G. Sonneck, "Benjamin Franklin's Relation to Music," *Music*, vol. XIX, Nov., 1900, pp. 1-14; Theodore Diller, *Franklin's Contribution to Medicine, Brooklyn*, 1912; William Pepper, *The Medical Side of Benjamin Franklin*, Phila., 1922; E. D. Ross, "Benjamin Franklin as an Eighteenth Century Agriculture Leader," *Jour. Pol. Econ.* XXXVII, 52-72 (Feb., 1929); E. L. Nichols, "Franklin as a Man of Science," *Independent*, LX, 79-84 (Jan. 11, 1906); M. W. Jernegan, "Benjamin Franklin's 'Electrical Kite' and Lightening Rod," *N. E. Quarterly*, I, 180-196 (April 1928), summarizing and superseding earlier discussions of this subject by A. Mc Adie and A. L. Rotch; and C. Abbe, "Benjamin Franklin as Meteorologist," *Proc. Am. Phil. Soc.*, XLV, 117-128 (1906). While these are mostly competent studies of their specific subjects, many of them make the mistake of suggesting that Franklin was interested in science exclusively for utilitarian reasons, and they neglect his interest in "pure" science and in its religious implications.

[149] Paine's *Writings*, ed. Conway, III, 327.

smokeless candles, a planing machine, an engine operated by gunpowder, a steam turbine, remedies for yellow fever, and a single-arch bridge. As a humanitarian legislator inspired by a deistic conception of service, he urged adequate salaries for excise men; abolition of slavery, of duelling, and of the death penalty; effective international copyright laws; better universal education; old age pensions; curtailment of primogeniture and of property inequalities, especially through an income tax; a league of nations; and international disarmament. "My religion," Paine said, "is to do good."[150]

The vast and varied humanitarian interests and inventions of Jefferson, based upon scientific principles, have been enthusiastically chronicled by Professor D. S. Muzzey.[151] As president of the American Philosophical Society[152] Jefferson did much to encourage his countrymen in the practical application of science to improving the environment, developing our natural resources, and the saving of time, energy and life. (An attentive study of *The Early Proceedings of the American Philosophical Society, 1744-1838* (Vol. XXII, Part 3, 1884) will reveal the almost incredibly numerous ways in which this great body stimulated the application of science to humanitarian purposes in the last half of the 18th century.) Jefferson's loyal henchman, Philip Freneau, inspired by scientific deism as we have seen, used his great gifts as a journalist in the *National Gazette*, "the

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[150] *Ibid.*, II, 472.

[151] D. S. Muzzey, "Thomas Jefferson—Humanitarianism," *American Review*, IV, 35-44 (Jan. 1926). See also his chapters on the subject in his book, *Thomas Jefferson* (New York, 1918). Jefferson was also interested in the abolition of slavery; see "Thomas Jefferson's Thoughts on the Negro," *Journal of Negro History*, III, 55-89 (Jan. 1918). See also R. H. Halsey, *How the President, Thomas Jefferson, and Dr. Benjamin Waterhouse Established Vaccination as a Public Health Procedure* (New York, 1936), and a review of it in *N. E. Quarterly*, IX, 523-28 (Sept. 1936).

[152] See *An Historical Account of the Formation of the American Philosophical Society*, by Stephen Du Ponceau, Philadelphia, 1914. According to the Preface to the first volume of the *Transactions* of this Society, "Knowledge is of little use, when confined to more speculation: But when speculative truth are reduced to practice, when theories, grounded upon experiments, are applied to the common purposes of life; and when, by these, agriculture is improved, trade enlarged, the arts of living made more comfortable, and, of course, the increase and happiness of mankind promoted; knowledge then becomes really useful. That this Society, therefore, may in some degree, answer the ends of its institution, the members propose to confine their disquisitions, principally, to such subjects as tend to the improvement of their country and advancement of its interests and prosperity." The anonymous *Early History of Science and Learning in America* (Phila., 1943) deals mainly with the American Philosophical Society. The *Memoirs of the American Academy of Arts and Sciences* (Boston, 1785, I, 3-4) emphasize the utility of Science also.

leading paper in America," in 1791-93 to broadcast humanitarian ideas. Their dependence on science is clear:

"The lovely philanthropic scheme
(Great image of the power supreme,)
On growth of science must depend
With this all human duties end."[153]

Freneau advocated aid for the alien, the poor, and the oppressed, as well as abolition of slavery, kindness to animals, and material improvements such as better roads.[154] Thomas Cooper, friend of Paine and the scientist Priestley who came to America in 1794, turned from science to humanitarianism. *His Letters of the Slave Trade* (1787) show his great sensitiveness to its inhumanity, and a contemporary testified to the countless ways in which he devoted his great talents to "the injured and the unfortunate."[155] As Malone sums up his work, Cooper "saw the hope of humanity in the work of scientists. . . ."[156] Dr. Benjamin Rush eventually turned orthodox in religion, but he was originally the close friend of Paine and Franklin. Hardly a deist, he was, however, a great scientist and environmentalist,[157] the most

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[153] *Poems of Freneau* (edited by H. H. Clark), New York, 1929, p. 417. The introduction of this book assembles evidence to show that scientific deism was the core of Freneau's thought.

[154] *Ibid.*, p. xxxix. See also Thomas Odiorne's *The Progress of Refinement* (1792).

[155] See Dumas Malone, *The Public Life of Thomas Cooper*, p. 20. After the turn of the century, when Cooper moved to South Carolina, he turned against abolition.

[156] *Ibid.*, 305.

[157] In keeping with this philosophy is the view expressed by Rev. Samuel Stanhope Smith in *An Essay on the Causes of the Variety of Complexion and Figures in the Human Species* as early as 1787. And belief in the principle of evolutionary natural selection was offered for the first time in this country by William Charles Wells. Rev. Smith explains variety among mankind as caused by climate. Thus the differences between the negro and the white man are due not to divine causes but to different environments, to natural causes, and the negro can be changed and improved. Color of the skin, for instance, depends upon the intensity of the sun's rays: "An ardent sun is able intirely [sic] to penetrate its [the skin's] texture—such an operation not only changes its colour, but increases its thickness." (p. 10) Bile also would cause a change to take place: "Bile exposed to the sun and air, is known to change its colour to black—black is therefore the tropical hue." (p. 12) Changes of complexion would be accompanied by corresponding changes in the color of hair. (p. 27) "Coarse and filthy unguents" (p 46) that savages use also would "create a dark and permanent colour."

Wells of South Carolina wrote *Two Essays: One Upon Single Vision with Two Eyes; the other on Dew . . . and An Account of a Female of the White Race . . . Part of Whose Skin Resembles that of a Negro* (1818); these essays had been read before the Royal Society in 1813. He was first in this country to assume that there had been a biological evolution of the human species, and "clearly explained the principles of a natural selection in the course of a struggle for existence and a consequent survival of the fittest." (*Dictionary of American Biography*, vide Wells). Darwin, in the fourth [1866] edition of his great work, pays tribute to Wells: "In this paper he [Wells] distinctly recognizes the principle of natural selection, and this is the first recognition which has been indicated. . . ." (introduction).

eminent physician in the colonies at the time, and our first psychiatrist.[158] He vied with Franklin in the multitude of his humanitarian activities, and is especially notable for his *Inquiry into the Influence of Physical Causes Upon the Moral Faculty* (Phila., 1786). In this oration before the American Philosophical Society this man (who taught more physicians than any other teacher of the time) reveals himself as a distinguished pioneer in working on the theory, inspired by science, that because many wrong-doers are determined by physical causes beyond their control they are entitled not to punishment but to sympathy and scientific aid. "It is perhaps," Rush said, "only because the disorders of the moral faculty, have not been traced to a connection with physical causes, that . . . so few attempts have been hitherto made, to lessen or remove them by physical as well as rational and moral remedies."[159]

Thus science led to a humane basis for sympathetic treatment of certain classes of criminals and the criminally-insane which foreshadowed the work which was to be done by determinists such as Clarence Darrow and Harry Elmer Barnes over a century and a quarter later.

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[158] See N. G. Goodman, *Benjamin Rush: Physician and Citizen.* Phila., 1934, Chapter XI, "First American Psychiatrist," and Chapter XII, "Reformer and Philosopher." Rush was a pioneer in prison reform, in abolition, in prohibition, in the kindly treatment of the insane, and in many other reforms. Following John Mitchell, he did a great humane work in furthering remedies for the tragic Yellow Fever epidemic of 1793. See Joseph Mc Farland, "The Epidemic of Yellow Fever in Philadelphia in 1793, and its Influnce upon Dr. Benjamin Rush," *Medical Life,* XXXVI, 449-496. This is a critical study of Rush's status as a physician. See also W. T. Howard, *Public Health and Administration and the Natural History of Disease in Baltimore, Maryland, 1797-1920.* Wash., 1923. Noah Webster, who was a good deal of a scientist, "proposed unemployment insurance, city planning, cleansing of streets, improvements of penal laws, investigation of diseases, collection of statistics, forest conservation, organization of charity societies; he advocated the government's purchase and freeing of slaves; he developed a fuel-saving fireplace; he wrote a history of commerce and the first pages of a history of epidemics." H. R. Warfel, *Noah Webster* (New York, 1936, p. 225.) See Webster's "A Short View of the Origin and Progress of the Science of Natural Philosophy, with Some Observation on the Advantages of Science in General," in *New York Magazine,* Vol. I, June-July 1790. Also C. E. M. Morey, "The Epidemiology of Noah Webster," *Trans. Conn. Acad.,* XXXII, 21-109 (1934); and Warfel, Chapter XII.

[159] *Rush's Inquiry* . . ., p. 15. Another physician-author, Oliver Wendell Holmes, later developed Rush's thesis that determinism should inspire us to pity and not punish certain sorts of criminals. See Holmes' "Crime and Automatism," 1875, in *Works,* VIII, 322-60.

## IV

### EDUCATION

Let us turn now to a consideration of the extent to which Americans of the later eighteenth century turned to education (which in their eyes was almost equivalent to rationalism and science) as the most effective agent in human improvement. It is true, of course, that some of the earlier British thinkers of the century, such as Locke, Pope, and Hume, had spoken of the limitations of the reason, especially in the metaphysical and supernatural realms, as a means of furthering human happiness and grasping "absolutes": "the bliss of man" was to them partly conditioned upon *not* thinking "beyond mankind."[160] But the increasing faith in human reason as a means of improving man's lot in this world is represented[161] by William Godwin, whose *Enquirer: Reflections on Education, Manners, and Literature*, which first appeared in England in 1793, was sufficiently popular in America to warrant an edition in Philadelphia in 1797. His central chapter (No. V) in *Political Justice* (1793), written partly to refute Malthus' pessimistic views based on the disparity between increases in population and food-supply, had for its title the axiom: "The Voluntary Actions of Men Originate in their Opinions." In this chapter he deduced from these principles "the five following propositions":

> "sound reasoning and truth, when adequately communicated, must always be victorious over error; sound reasoning and truth are capable of being so communicated; truth is omnipotent; the vices and moral weakness of man are not invincible; man is perfectible, or, in other words, susceptible of perpetual improvement."

After contrasting man "in his original state" with contemporary man as the heir of "all that science and genius have effected"—surrounded with "manufactures, instruments, machines, together with all the wonders of painting, poetry, eloquence and philosophy"—Godwin concludes, "Such was man in

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[160] *An Essay on Man* (1732), Epistle I, 11.189ff.

[161] Legouis and Cazamian, *A History of English Literature*, New York, 1929, Vol. II, p. 1004, regard Godwin as "the chief intellectual representative of the more advanced party"; and A. O. Hansen, *Liberalism and American Education*, New York, 1926, p. 15, calls him "most ideally representative of the eighteenth century outlook in his conception of education."

his original state, and such is man as we at present behold him. Is it possible for us to contemplate what he has already done, without being impressed with a strong presentiment of the improvements he has yet to accomplish? There is no science that is not capable of additions; there is no art that may not be carried to a still higher perfection," and, he suggested, "If this is true of all other arts, why not of social institutions?"[162] Now Thomas Paine had been so closely associated with Godwin in England, and so thoroughly in agreement with his views, that he had entrusted Godwin[163] with the task of seeing the first part of *Rights of Man* through the press in 1791. Jefferson had been instrumental in securing an American edition of *Rights of Man* in the same year and he admitted that he "professed the same principles,"[164] among which was the central one of faith in the omnipotence of reason.[165] To such eighteenth century figures as Godwin, Paine, and Jefferson, then, man was a reasoning animal whose actual conduct was merely the externalization of his ideas; man was to be regenerate by enlightening him, by giving him the right ideas, or by changing those he inherited from monarchy and established religions; institutions, whether of church or state, which interfered with the free play of reason, must be overthrown or at least modified. Education, as the means of furthering science, was the Messiah; educators were merchants of light.

Franklin, Jefferson, and Rush founded colleges in this period; Thomas Cooper was president of South Carolina College;

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[162] *Political Justice*, 1793, I, 41, 47.

[163] See M. D. Conway, *Life of Thomas Paine*, I, 284. For Godwin's praise of Paine's ideas, see *Political Justice*.

[164] Jefferson's *Writings*, Memorial Edition, 1907, VIII, 207.

[165] Further testimony as to the importance attached to the liberals' views of education as a means of indefinite progress is suggested by its being singled out for attack by their Presbyterian-conservative opponents. Thus Samuel Miller (*Retrospect of the Eighteenth Century*, New York, 1803, II, 296-302) writes: "This doctrine, of the *omnipotence of education* [note the phrase!] and the *perfectibility* of man, seems liable . . . to the following strong objections." Then he develops the following: (1) It is contrary to nature and the condition of man. (2) It is contrary to all experience. (3) It is contrary to the increase of population compared with the means of subsistence (the argument of Malthus that Godwin wrote in part to refute). (4) It is wholly inconsistent with the scriptural account of the creation and the present state of man. It is conceivable that Hawthorne's early study of Godwin may have led him in part to react against him, to take as one of his master-themes the perils of the pride of intellectuality as militating against a sympathetic heart and human brotherhood (cf. "Ethan Brand") and the ineffectualness of rational-knowledge alone to produce that quickening of spirit and the will necessary for the actual practise of virtue.

and Tom Paine had strong views on education. In general, these thinkers tended to advocate an education which emphasized empiricism as against the authority of tradition, the study of nature as against the study of man, and practical utility as against a delight in learning for its own sake. Franklin had attacked the curriculum of Harvard as narrowly theological as early as 1722,[166] and he was strongly opposed to the linguistic study of the ancient Greek and Latin classics.[167] His two essays, "Proposals Relating to the Education of Youth in Pennsylvania" (1749) and the "Idea of the English School" (1751), do not introduce exceptional innovations in current practice, but his personal preferences had appeared in his "Proposal for Promoting Useful Knowledge Among the British Plantations in America," 1743.[168] In the latter the knowledge sought is to be almost exclusively scientific and utilitarian, having to do with farming, inventions, navigation, etc. He urges "all philosophical experiments that let light into the nature of things, tend to increase the power of man over matter, and multiply the conveniences or pleasures of life."[169]

The cultured Jefferson had much more respect than Franklin for what he called the "luxury" of the ancient classics.[170] But Mr. Chinard has shown, as mentioned earlier, that his choice of the classics was dictated by his deistic tastes which seem to have been primary in importance; and his faith in progress led him to say, "I love the dreams of the future better than the history of the past." A militant agrarian, as his champion Mr. Parrington has shown, Jefferson regarded agriculture among all studies as "the first in utility, and [it] ought to be the first in respect." He wished to restore "agriculture to its primary dignity in the eyes of men. It is a science of the very first order. It counts, among its handmaids, the most respectable sciences, such as

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[166] Franklin's *Writings* (ed. Smyth), II, 9-14.

[167] *Ibid.*, X, 29; X, 31.

[168] The first two essays are reprinted conveniently in the Mott-Jorgenson *Franklin* (1936), pp. 199-213, and the last, *ibid.*, pp. 180-183. A. O. Hansen, *Liberalism in American Education in Eighteenth Century* (New York, 1926), pp. 265-292 lists a multitude of essays on Education, many of which were inspired by science. For further discussion see F. N. Thorne, *Benjamin Franklin and the University of Pennsylvania*; Thomas Woody's *Educational Views of Benjamin Franklin*; and T. H. Montgomery, *A History of the University of Pennsylvania.*

[169] Mott-Jorgenson, *op. cit.*, p. 182.

[170] See Chinard's Introduction to Jefferson's *Literary Bible* (Baltimore, 1928); R. J. Honeywell's *The Educational Work of Thomas Jefferson* (Cambridge, 1931).

chemistry, natural philosophy, mechanics, mathematics generally, natural history, botany. In every college & university a professorship of Agriculture, & the class of its students, might be honored as the first."[171] It is significant that in 1779 Jefferson abolished the professorships of divinity at the College of William and Mary to provide for those of law, medicine, chemistry, and modern languages.[172] Foreign, also, to orthodox classical education was Jefferson's encouragement of specialization and his pioneer advocacy (long before President Eliot) of the elective system.[173] Jefferson was also a pioneer in founding vocational education for "the limited wants of the artificer or practical man,"—for would-be utilitarian scientists such as the "pump-maker, clock maker, machinist, optician," etc.[174] He helped, then, to turn education away from the classical ideal of its being an ethical guide to the happy conduct of life to the ideal which makes it a means for material ends, although it should be added that Jefferson, following the philosophy of environmentalism (based partly on Locke and science), thought the circumstances of the farmer's life would be conducive to happiness. And this turn seems to have been inspired considerably by science and by an agrarianism which rested in part upon the doctrine that the earth is a divine revelation and hence the farmer is nearest to God.[175] This was the view of the man who is generally regarded as the chief theorist of Jeffersonian democracy, John Taylor of Caroline (1753-1824). He not only strongly opposed the financial-industrial policy sponsored by Hamilton in the North, but as the author of sixty-one "agricultural essays, practical and political" (collected in *The Arator*, 1813), he laid the ideological basis for agrarianism. A. O. Craven

[171] Jefferson's *Writings*, Randolph Ed., IV, 9-10. To David Williams, Nov. 14, 1803.

[172] Cabell, *Early History of the University of Virginia*, p. 207.

[173] See Jefferson's letter to Ticknor, July 16, 1823. Memorial Ed., XV, 455. In place of the classical policy of a uniformly rounded education, Jefferson advocated students' "exclusive application to those branches only which are to qualify them for the particular vocations to which they are destined. We shall . . . allow them uncontrolled choice in the lectures they shall choose to attend. . . ." See also H. B. Adams, *Thomas Jefferson and the University of Virginia* (1888), Chapter IX, "The University of Virginia and Harvard College." O. W. Long, *Thomas Jefferson and George Ticknor, A Chapter in American Scholarship* (Williamstown, Mass., 1933) prints many hitherto unavailable letters which prove that "Jefferson inspired young Ticknor in his efforts for reforms at Harvard, especially in the direction of elective studies." (p. 39).

[174] Cabell, *op. cit.*, p. 384. (To Peter Carr, Sept. 7, 1814).

[175] See John Taylor's *Arator*, pp. 278-80, and the interpretation of H. H. Simm's *John Taylor* pp. 155-6. Also Jefferson's *Writings*, Memorial Edition, II, 229-30.

calls Taylor the greatest scientific agriculturalist of his era.[176]

Jefferson was an ardent admirer of Thomas Cooper, before Cooper turned conservative in the nineteenth century, and he hoped to secure a professorship for him at the University of Virginia, thinking of him as "the corner stone of our edifice."[177] It is true that Cooper advocated[178] the study of the classics by young boys, but his revolt from the humanities to utilitarian science is illustrated in his view that an interest in literature is something with which childish people are "disgracefully employed" when they should be devoted to "those laws on which all useful manufactures depend. . . . In the infancy, and the ignorance of all communities, the great objects of intellect are poetry and oratory; as nations advance in knowledge, science gains a rightful ascendency."[179] "Most of his [Cooper's] scientific writings were designated to extend popular scientific information on subjects of practical concern. Thus he edited the *Emporium of Arts and Sciences* (1813-14), published practical treatises on dyeing and calico printing, gas lights, and the tests of arsenic, and edited several European textbooks in chemistry for the use of American students. The most interesting of his more theoretical writings are his description of the scientific discoveries of Priestley (in Appendix I of the latter's *Memoirs*, 1806), his *Introductory Lecture on Chemistry* (1812), and his *Discourse on the Connexion between Chemistry and Medicine* (1818), in which as usual, he was forward looking. These writ-

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[176] See A. O. Craven, "Soil Exhaustion as a Factor in the Agricultural History of Virginia and Maryland, 1606-1860," in University of Illinois *Studies in the Social Sciences*, XIII, 1925. For orientation see R. H. True, "Beginnings of Agricultural Literature in America," *American Library Assocation Bulletin*, No. 14, 1920; R. H. True, "Early Development of Agricultural Societies in the U. S.", *Report of the American Historical Assoc.*, 1920; R. W. Kelsey, "Material for the History of Early Agriculture in Pennsylvania," *ibid.*, and Rodney C. Loehr, "The Influence of English Agriculture on American Agriculture, 1775-1825," *Agricultural History*, Jan. 1937. Taylor was one of the leading members of "The Philadelphia Society for Promoting Agriculture," organized in 1787. The latest and most comprehensive work on him is E. T. Mudge's *The Social Philosophy of John Taylor.*

[177] Quoted, Malone, *op. cit.*, p. 245.

[178] See his educational essays, "Classical Education" (*Port Folio*, 2 series, I, 567ff.), "A letter to a Friend on University Education" (*ibid.*, 3 series, V, 349ff.) "On a Course of Legal Studies" (*ibid.*, 4 series, XIII, 227ff.). For discussion see Maurice Kelley's *Cooper* (1930), pp. 63ff.

[179] *Introductory Lecture on Chemistry*, 1812 (London) pp. 13-14. He adds that "When experience has taught us wisdom, we begin to estimate *utility* as the criterion of desert. . . ." In *Lectures on Political Economy*, p. 182, he says that because of the gifts of scientists to humanity the whole "tribe" of poets and orators and rhetoricians will eventually sink into "merited insignificance." Quoted by Malone, *op. cit.*, pp. 254, 305.

ings serve as a valuable index to the state of American scientific knowledge in his day and reveal his own consistent faith in salvation by enlightenment."[180]

Equally radical in his educational views was Cooper's idol, Tom Paine. Unlike most religious thinkers who have seen the deity revealed not only in outward nature but within themselves in psychological promptings toward goodness, Paine concluded *The Age of Reason* with the conviction that "we can know God only through his works," through outward nature. "The principles of science lead to this knowledge; for the Creator of man is the Creator of science, and it is through that medium that man can see God, as it were, face to face."[181] While the study of theology in books has led to persecution, Paine says the "mind becomes at once enlightened and serene" when man looks "through the works of creation to the Creator himself,"[182] for "the Almighty is the great mechanic of the creation; the first philosopher and original teacher of all science."[183] Hence astronomy, the queen of the sciences, "should be taught theologically" in a series of lectures which would "render theology the most delightful and entertaining of all studies."[184] Paine would therefore turn every "house of devotion into a school of science" dedicated to teaching "the immutable laws of science."[185] Since he imagined that the church feared science and had confined learning to the dead languages, he thought "it would therefore be advantageous to the state of learning to abolish the study of the dead languages, and to make learning consist, as it originally did, in scientific knowledge."[186] Nature speaks a universal language and "reveals all that it is necessary for man to know of God." Study of the humanities should be abolished, and the sole subject matter of education should be the sciences. It would be interesting to know to what extent these ideas of Paine's were derived from Dr. Benjamin Rush, who coached him in writing

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[180] *Dictionary of American Biography.*

[181] *Works*, ed. Conway, IV, 191.

[182] *Ibid.*, IV, 239-40.

[183] Paine's *Works*, IV, 193. "Natural philosophy is properly a divine study. It is the study of God through his works . . . . All the principles of science are of divine origin." *Ibid.*, IV, 238-9.

[184] *Ibid.*, IV, 246.

[185] *Ibid.*, IV, 194.

[186] See *Age of Reason*, Part One, Chapter XII, "The Effects of Christianism on Education. Proposed Reforms," *Works*, IV, 55-62.

*Common Sense,* 1776. For Rush, the founder of Dickinson College, was almost equally opposed to education based on the classics, although not so much for theological as for utilitarian and democratic reasons. Witness Rush's hostile "Observations upon the Study of the Latin and Greek Languages" (1789),[187] and his other numerous writings on education.[188] In addition to attacking the classics as lacking in utility and as foreign to democratic sentiments, he adds that "The study of the Latin and Greek classics is unfavorable to morals and religion," while "a servile attachment to the ancient poets . . . checks invention and leads to imitation." Rush's "Plan for Establishing Public Schools in Pennsylvania, and for Conducting Education Agreeably to a Republican Government" (1786) advocated free schools and four colleges in the state in which students were to concentrate on mathematics and science. These colleges were to be capped by the apex of the educational pyramid, a national university which would concentrate in turn upon fitting students as servants of our distinctly democratic nationalism. His "Address to the People of the United States" (1787)[189] and his "Plan of a Federal University" (*Federal Gazette,* Oct. 29, 1788) demanded that this great national or federal university should be established as a sort of post-graduate civil service training school. A militant republican nationalist, he would limit eligibility to public office to holders of degrees from this university controlled by the government and designed to inculcate political propaganda[190] for a nationalism which was hostile to the ideals of other nations and to European traditionalism.

On the other hand, it should be remembered that these extreme projects for founding a national university and making

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[187] *American Museum,* V, 525-35 (June, 1789), reprinted in his *Essays, Literary, Moral,* etc., (1789), with the above abbreviated title.

[188] Harry G. Good, *Benjamin Rush and his Services to American Education* (Berne, Indiana, 1918), lists, pp. 260-63, sixteen items by Rush on education. For further discussion, beside Good's dissertation, see N. G. Goodman, *Rush,* 1934, pp. 307-342, and A. O. Hansen, *Liberalism and American Education in the Eighteenth Century* (New York, 1926, pp. 48-63.)

[189] *American Museum,* I, No. I, 8-11, Jan. 1787.

[190] Mr. A. O. Hansen's closely-documented book shows how pervasive in the late 18th century was the idea, bred by the doctrine of progress, that America ought to have a new kind of education divorced from tradition and devoted to the inculcation of utilitarian and nationalistic doctrines. It is probable that the idea of progress, inspired by science, accounts for a considerable amount of the contempt for the past, for European traditionalism, and so does much to explain the great vogue of the demand for a uniquely American literature which is so prominent in this period. But that is an intricate subject which must be reserved for another paper.

education narrowly nationalistic failed, and that a more important influence of science was to lead thinkers to transcend nationalities and to become citizens of the whole world in their devotion to truths that are universal. In a study of "Scientific Relations between Europe and America in the Eighteenth Century" Dr. Michael Kraus presents a mass of interesting evidence to illustrate the contemporary view that in the promotion of scientific utilitarian devices "the world is but as one Family," that (as Dr. Rush wrote the British Dr. Richard Price), "In science of every kind men should consider themselves as citizens of the whole world."[191] It will be recalled that Franklin, Barlow, and Paine crowned their political theories—which owed much to scientific ideas—by espousing something like a League of Nations to promote international fellowship and eliminate wars bred by conflicting nationalisms. The reasoning, involving science as inspiring cosmopolitanism and a philanthropy which transcends nationalisms, may be illustrated from Thomas Paine:

> "Men who study any universal science, the principles of which are universally known, or admitted, and applied without distinction the common benefits of all countries, obtain thereby a larger share of philanthropy than those who only study national arts and improvements. Natural philosophy, mathematics and astronomy, carry the mind from the country to the creation, and give it a fitness suited to the extent. It was not Newton's honor, neither could it be his pride, that he was an Englishman, but that he was a philosopher: the heavens had liberated him from the prejudices of an island, and science had expanded his soul as boundless as his studies."[192]

Much is being said today about science (through munitions and machines of destruction) being responsible for the horrors of war. It is well to remember that at the birth of the nation at least science helped to inspire not only a multitude of means of increasing human happiness but also anti-warlike and cosmopolitan attitudes which furthered world peace.

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[191] *The Scientific Monthly*, LV, 259-272 (Sept., 1942). The quotations above are from the *Gentleman's Magazine* (1800, pp. 1273-74) and the Massachusetts Historical Society *Proceedings*, second series, Vol. 17, April 22, 1786. See also Dr. Kraus' article on "American and European Medicine in the Eighteenth Century," *Bulletin of the History of Medicine*, VIII, 679-95 (May, 1940).

[192] Paine's *Writings*, ed. Conway, I, 300. See also *Poems of Freneau*, ed. Clark, p. 383.

An immense amount of work remains to be done on American literature of this period during which our national traditions came into being. Most of the writings of Rush, Rittenhouse, Ethan Allen, Thomas Cooper, not to mention nearly all of Freneau's prose, remains to be made accessible in scholarly editions. Professor Verner Crane has recently made discoveries which more than double the present corpus of Franklin's political writings. But the additional writings have not yet been collected and published.[193] A great number of monographs on special topics need to be written. If the arguments of the liberals are not to appear as shadow-boxing, we need to reconstruct the logical articulation of the pattern of ideas of the *conservatives* (such as John Adams) which were grounded essentially upon the classical and the Christian traditions. We can hardly understand the liberals without understanding the conservatives. We need to transcend the provincial, chauvinistic approach to our national letters by including it in the comparative-literature approach, especially in this cosmopolitan period. An especially rich field of investigation is that involving the extent to which English and Continental ideas were known in America, and through what precise channels. How and why were these trans-Atlantic ideas modified by being transplanted to the American environment? If sentimentalism had less vogue and influence than in Rousseau's France and Cowper's England, what explains this situation? Ideas about economics and literary style as related to science offer a fascinating field for investigation. Does the theory of *laissez-faire* find a philosophic sanction in part in the Newtonian idea of the harmony of self-love and social and of the presence of beneficent natural laws? If agrarianism dominated the economic thinking of leaders such as Franklin and Jefferson, to what extent was agrarianism rooted in scientific, deistic, and Physiocratic ideas? To what extent did scientific inventions[194] in the midst of the vast physical resources and the physical needs of a frontier country inspire manufacturing and

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[193] V. W. Crane, "Certain Writings of Benjamin Franklin on the British Empire and the American Colonies," *Papers of the Bibliographical Society*, XXVIII, Part I, 1-27 (1934). Students of the whole period will find W. M. Smallwood's general bibliography very useful; see his *Natural History and the American Mind*, New York, 1941, pp. 355-424. And there is much that is highly suggestive regarding the influence of science in Merle Curti's *Growth of American Thought*, New York, 1943.

turn American life gradually from rural to urban social patterns? In matters of literary style, to what extent did science help to inspire "mathematical plainness"; a didactic and utilitarian hostility to a literature of delight; ordered argument and logic; devotion to the local and the sensuous (nature and not a book being a divine revelation); hostility towards the past and toward imitation; and a self-sufficient and unique nationalism bred by the idea of progress? It is much too early to try to speak with finality regarding any of these problems. I hope, however, that this paper,[195] written more to suggest hypotheses than final interpretations, may help to suggest the desirability of more intensive genetic study of the logical articulation of ideas in this seminal period, especially those that are rooted in science and flower in religious, political, humanitarian, educational, and literary ideals and attitudes. It is true that environmental factors—notably the frontier and English oppression—reinforced these ideas. But ideas would seem to be especially important in an age when men such as Godwin and Paine prided themselves upon making action the externalization of central philosophic principles.

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[194] See Holland Thompson, *The Age of Invention*, New Haven, 1921, and his bibliography.

[195] I should like to express my thanks to Professor R. S. Crane for many valuable suggestions made when this paper was in first-draft. But since he has not seen it in its present form, I do not know, of course, to what extent he will approve of it.

# DEER IRRUPTIONS

*Compiled by Aldo Leopold for the Natural Resources Committee, Wisconsin Academy of Sciences, Arts and Letters. (Aldo Leopold, Ernest F. Bean, Norman C. Fassett)*

## *Foreword*

It is my belief that the Wisconsin Academy, particularly through the members in the various educational institutions throughout the State, should provide scientific data that can be used as a basis for formulating public policy on the conservation and utilization of our local natural resources. With the approval of the Council, a standing committee on natural resources has been appointed to this end. The present paper is the first of a series of reports bearing on the State's conservation problems—A. W. Schorger, President.

From the fifteenth century until 1910, the deer problem of North America was a matter of too few, rather than of too many.

About 1910 the Kaibab deer herd in Arizona, long stabilized at a level of about 4000 head, began to pyramid its numbers. By 1918 the range showed overbrowsing (21, p. 237). Between 1918 and 1924, seven successive investigators warned of impending disaster, but nothing was done (16, pp. 11-13).

In 1924, at a probable level of 100,000 head, came the first of two catastrophic famines which reduced the herd 60 per cent in two winters. By 1939 the herd had dropped to a tenth of its peak size, and the range had lost much of its pre-irruption carrying capacity.

This was the first of a series of irruptions which have since threatened the future productivity of deer ranges from Oregon to North Carolina (22), California to Pennsylvania (8), Texas (23) to Michigan (1). Wisconsin is one of the more recent irruptive states.

This paper aims to present a background for the present Wisconsin problem.

### *Histories*

Diagrammatic histories of four irruptive deer herds appear in Figures 1 and 2. Each of these herds is a self-contained population, either by reason of geographic extent or by reason of natural or artificial barriers.

*(A) George Reserve.* This enclosed range, owned and operated by the University of Michigan, was stocked with four does

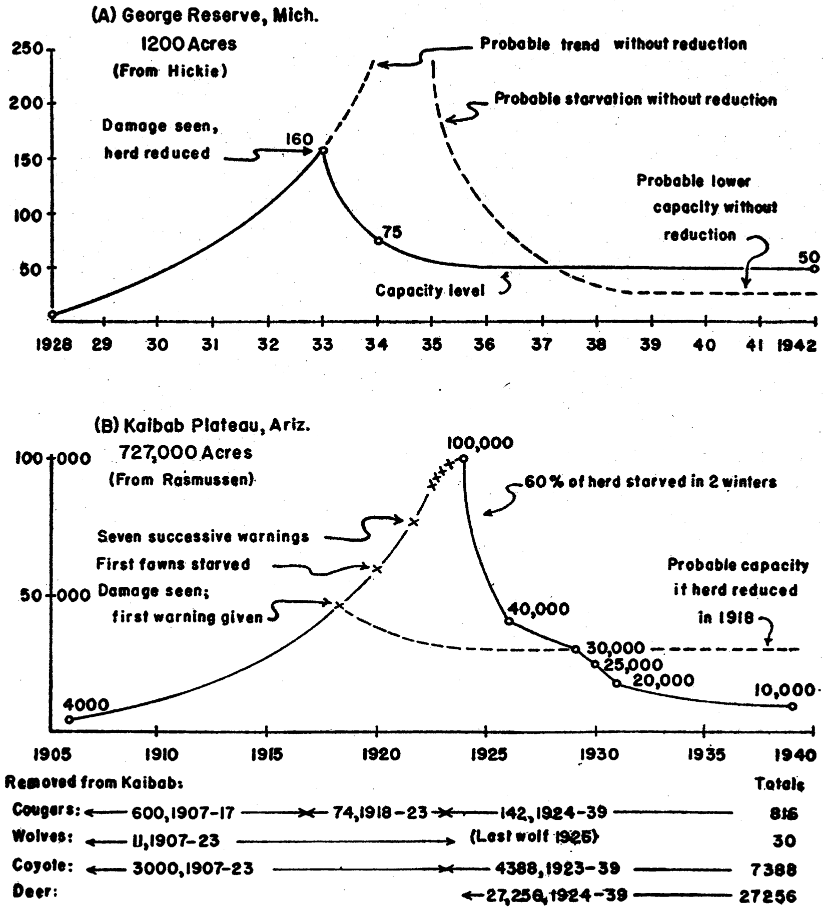


FIGURE 1. Effect of prompt vs. delayed removals on carrying capacity for deer. Herd A was promptly reduced, and now stands at a higher level than would prevail if starvation had been permitted. Herd B was allowed to starve, and now stands at a lower level than would prevail if prompt reduction had been made.

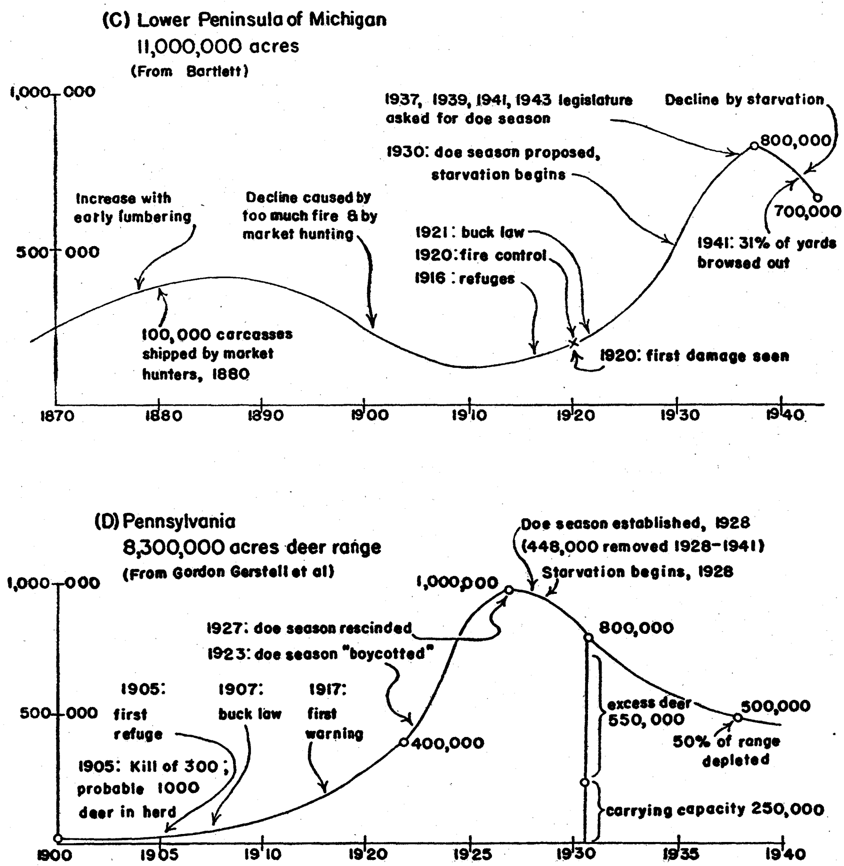


FIGURE 2. Effect of delayed herd reduction in Michigan and Pennsylvania. The Michigan herd has passed the fawn-dying stage, and starvation of adults is now started. The Pennsylvania herd was reduced, but not until eight years after the first warning. Probably as a result of this delay, both the herd and the range are on the downgrade.

and two bucks in 1928. In 1933 overbrowsing became visible. A census showed 160 deer present. This is the maximum possible increase from four does in six years. (12) There is no doubt, therefore, that this herd had actually started to irrupt.

The herd was immediately shot down to 75 head, and later to 50 head, and is now being held at the 50 level by annual removals. The evidence of overbrowsing has disappeared. The reduced herd is in equilibrium with its range. This is one of the few known cases in which an incipient irruption was checked by prompt and decisive management measures.

*(B) Kaibab Plateau.* Unlike the George Reserve irruption, which was terminated by removing deer, the Kaibab irruption terminated itself by starvation. Some deer were in fact removed, but only after starvation had begun. The period of six years between the first warning (1918) and the final catastrophe (1924) was consumed in debate and litigation (16, p. 11).

The effect of prolonged overstocking on the winter food plants was very severe. In 1931, after four-fifths of the herd had starved and only 20,000 deer were left, one investigator says "the range had been so severely damaged that 20,000 was an excessive population. The herd continued to decrease slowly until an estimated 10,000 were present in 1939" (21, p. 237).

Another investigator estimates the loss in carrying capacity as high as 90 per cent in some areas (3, p. 369).

In short, the Kaibab, by reason of the irruption, lost a large part of its deer food without any gain in deer.

The dashed line in Graph B, Figure 1, indicates the probable trend of carrying capacity, had the herd been reduced in 1918, when range damage was first recognized. This hypothetical line corresponds to the actual history of the George Reserve herd, which was reduced after the first appearance of range damage.

*(C) Michigan.* Both the Upper and Lower Peninsulas have experienced two peaks in their deer herds, the first occurring soon after the first large-scale logging operations, and the second at the present time. The Upper Peninsula herd has lagged somewhat behind the lower in its time-schedule, due no doubt to the later loggings. The combined population in 1938 was estimated at 1,172,000 deer (1, p. 58).

Graph C, Figure 2, shows the history of the Lower Peninsula herd (1).

The size of the herd during the 1880-1890 peak is unknown, but no starvation and no range damage are on record, hence the peak cannot be regarded as of irruptive proportions. The increase in deer up to 1880 was probably caused by the opening up of the woods and the widespread reproduction of white cedar and other valuable browse plants (1, p. 10). The decline after 1880 was probably due to too much fire, and to commercial hunting and hunting for lumber camps. "More than 100,000 deer (were) shipped from northern Michigan stations during the fall of 1880 by market hunters" (1, p. 12).

The lower peninsula herd "hit bottom" about 1910. By 1925 the present peak was in the making (1, p. 14). Its inception coincides with the inauguration of a buck law (1921), an effective system of fire control (1920), a refuge system (1916-1932), better law enforcement, and wolf-control.

There is no reason to doubt that these changes, collectively, are the cause of the present irruptive behavior of the Michigan herd.

Range damage was first reported in 1920 (1, p. 47). The "cutting out" of many logging operations brought widespread starvation by 1930 (1, p. 48). In 1938 a survey of 300 winter yards showed "40 per cent in good condition, 27 per cent medium, and 33 per cent completely browsed out" (1, p. 49). The 1941 status was about the same.

The remedy, according to the Michigan Department, is to "take a limited number of antlerless deer in addition to the bucks" (1, p. 64). This was first proposed to the legislature in 1930, again in 1937, 1939, 1941, and 1943, but it remains a proposal.

Except for a few differences in dates and numbers, the upper peninsula herd presents a parallel history.

At the present writing the Michigan herd is shrinking by starvation, and with it shrink the good foods. It is an open question whether prompt reduction of the herd a decade ago would not have left Michigan with more food and just as many deer as she has today.

*(D) Pennsylvania.* The Pennsylvania deer herd dwindled steadily from Revolutionary times until about 1905, when it was nearing extermination. In that year the first refuge was established (20, p. 12). In 1907 a buck law was passed. By 1922, 30 refuges were in operation (20, p. 15), and the annual kill of deer had increased in fifteen years from 200 to 6115 (20, p. 12). The herd in 1922 stood at about 400,000, and was increasing rapidly.

Joseph Kalbfus predicted as early as 1917 that the deer herd would some day get out of hand. He recommended a doe season every fifth year, but his advice went unheeded. In 1923 the Commission opened a limited local doe season, but sportsmen killed it by "boycott." Their slogan was "Don't be yellow and kill a doe" (11, p. 16).

Local doe seasons were tried out in 1925 and 1926 (27, p. 8). In 1927, by which time the herd stood at 1,000,000, a statewide doe season was proclaimed by the Commission, but the sportsmen "marched on Harrisburg" and forced a rescinding order (11, p. 16). In 1928 an antlerless deer season was finally put into effect. That this action was too long delayed is indicated by the wholesale starvation of fawns during the two ensuing winters (27, p. 29).

In 1931, the Pennsylvania herd was estimated at 800,000, and the carrying capacity of the range at 250,000 (4, p. 33). In other words, even after the Pennsylvania herd had been reduced 20 per cent, the range was still 220 per cent overstocked.

Between 1931 and 1941 five antlerless deer seasons disposed of 448,000 does and fawns (2, p. 7), but large-scale starvation, including adult deer, was still prevalent in 1938, when the herd had shrunk to 500,000 (8, p. 13). "Runting" by malnutrition was still widely prevalent (9). Equilibrium between the shrinking herd and its food plants was finally reached in 1940 (2, p. 6).

Deer damage to crops in Pennsylvania has been prevalent since 1915, and to forests and plantations since 1922 (4, p. 6). In 1938 "excess deer (had) in many sections resulted in the complete overthrow of natural forest regeneration, and made forest planting practically impossible" (9, p. 27). "Due to scarcity of food in the forests, wild deer were encroaching in hordes upon neighboring farms. Fencing one farm merely crowded the animals onto the neighbors' farms" (11, p. 17). A special survey made in 1938 showed that half the deer range was producing less than fifty pounds of food per acre, which was virtual depletion (10, p. 6).

The Pennsylvania herd now stands at about 500,000 or half the 1927 peak level. The reduction is the combined result of doe-removal, starvation, and range deterioration.

It is an open question whether the Pennsylvania history is not an example of "too little and too late." A splendid initial success in management of deer has been partially cancelled out by delayed public acquiescence in herd-reduction.

### *Common Characters*

These histories exhibit certain common characters of deer herds, of deer food plants, and of human attitudes toward deer, which seem worth recording as background for the Wisconsin problem.

They also exhibit a common sequence of stages which may help to interpret current events, to anticipate research needs, and to guide administrative policy.

*Winter Food.* Deer irruptions are a problem in winter food. The summer range usually exceeds the winter range in carrying capacity.

Except in agricultural regions where deer have access to corn, alfalfa, or winter grains, deer subsist in winter mainly on twigs, buds, and catkins of woody plants, i.e., "browse." The browse species differ in palatability. Many investigators have shown that palatable browse is nutritious browse, while unpalatable browse cannot sustain deer in winter (1, p. 39; 17, p. 20; 7, p. 21).

As a herd increases, the pressure on palatable browse plants weakens them and ultimately kills them. It also prevents their reproduction, or the emergence of their reproduction above snow-level. Artificial plantings to reestablish browse are eaten up before they have a chance to grow (2, p. 6).

The unpalatable species are thus given a competitive advantage over palatable ones, and replace them. Thus in over-browsed Wisconsin winter deer yards white cedar, striped maple, red maple, red dogwood, and ground hemlock, all palatable, are being replaced by alder, aspen, and white birch, all unpalatable. This process of replacement of palatable by non-palatable winter food is shown in Figure 3. Replacement has been verified repeatedly in artificially "browsed" experimental quadrats.

Trees above the reach of deer are browsed up to the level which a mature deer can reach standing upright on its hind legs (six to eight feet). The species of trees which show such a "deer-line" are a sensitive index to the degree of deer-pressure

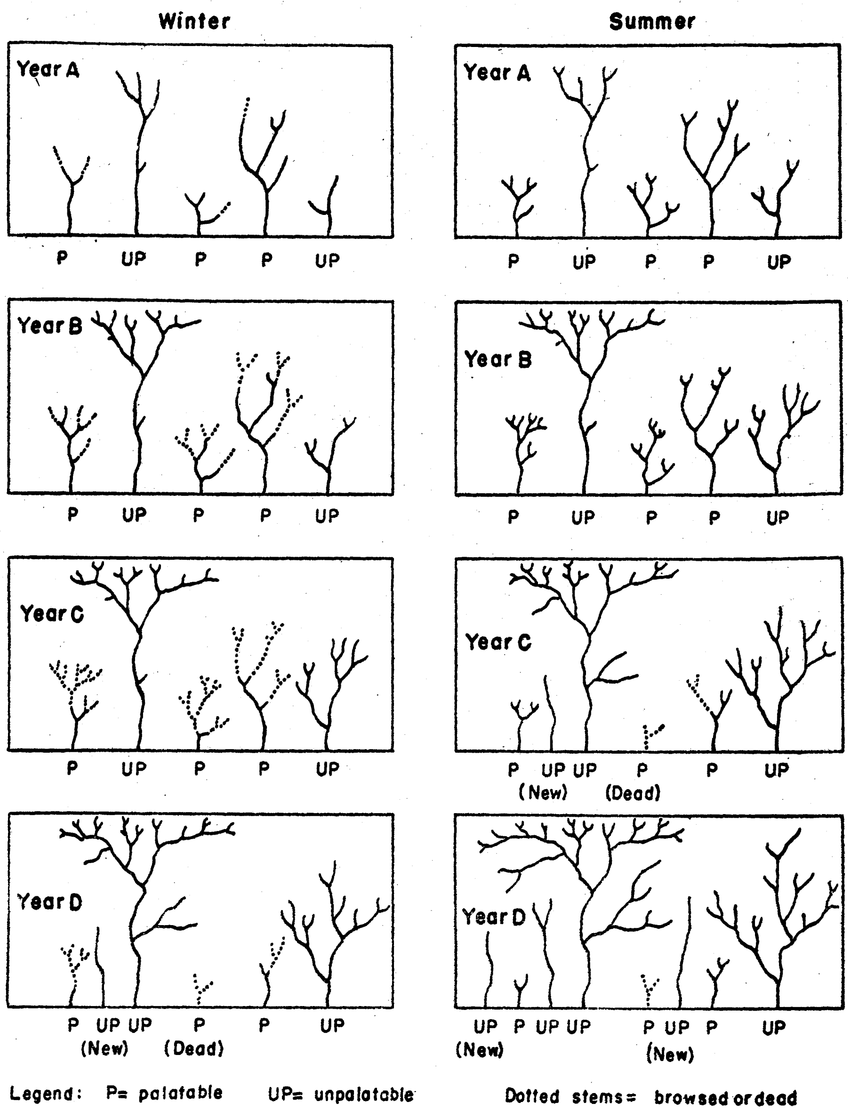


FIGURE 3. Effect of winter overbrowsing on composition of woody vegetation. The palatable species are gradually killed and replaced by unpalatable species. This process of replacement accounts for the low carrying capacity of overbrowsed ranges.

and its duration. A new deer-line on cedar and none on balsam shows an early stage of overbrowsing. A new deer-line on balsam plus an older one on white cedar shows an advanced stage. Fawns commonly starve at the stage when balsam or other poor foods first show a deer-line.

In other states these same principles hold, but for different plants. Thus on the Kaibab, deer pressure was first visible on cliffrose. As this good food became scarce, juniper and finally piñon pine were taken, and fawns began to die.

In Pennsylvania deer pressure was first visible on oaks, cherry, ash, maples, ground hemlock, and hemlock. As these became scarce, laurel, rhododendron, and pines were taken (4). Laurel is at the bottom of the preference list, but most of the fawns dying in 1928-29 had eaten it in quantity (27, p. 34). Many plants important to other game species were also depleted: thus greenbrier, on which ruffed grouse depend for cover, was nearly annihilated. Snowshoe hare and wild turkey likewise felt the pressure of excess deer. (Letter from Seth Gordon 6/15/43)

*Winter Deer Behavior.* Most animals, when crowded and hungry, disperse by their own social pressure. Deer herds, at least in winter, seem devoid of such pressure. State after state reports instances of deer stubbornly refusing to leave (or even to be driven from) (16, p. 18) a depleted winter range. Paraphrased in human terms, "deer would rather starve than move."

This trait results in *spotty* damage to the winter range. The Kaibab (21, p. 245), Pennsylvania (4, p. 21; 7, p. 19), New York (19, p. 12), and Michigan (1, p. 39) all report this spotty character, and it is now visible in Wisconsin. It confuses laymen, who see spots of undamaged winter browse and conclude that no crisis exists.

Perhaps wolves and cougars originally performed for deer the function of dispersal from congested spots which most species perform for themselves.

*Limitations of Artificial Feeding.* The first human reaction to deer starvation is always an impulse to feed the herd, rather than to reduce it. Winter feeding of game birds and songbirds carries no known penalties, why not feed the deer?

The main difference lies in the effect of artificial feeding on the supply of natural foods.

Game birds subsist in winter mainly on seeds (pheasant, quail) or buds (grouse). Both seeds and buds are produced in infinite quantity, and the consumption of seeds and buds does not affect next year's supply. Hence artificial food is a net addition to natural food.

Deer, on the other hand, subsist on palatable browse which is limited in quantity. Over-consumption progressively reduces next year's growth by attrition, non-reproduction, and replacement. Hence artificial deer food is not a net addition to natural food, and may become a net subtraction. For this reason, the most experienced states have come to doubt the wisdom of artificial feeding, except temporarily, or in emergency. For example, the Michigan Conservation Department says "winter feeding has not been successful, nor may it ever prove to be a feasible method of holding up declining deer populations" (1, p. 48). We doubt whether artificial feeding of deer is sound policy at any time, but we are certain that it is unsound to feed *before* the necessary herd-reduction has been made.

Experiments in semi-natural feeding by cutting trees or limbs have been conducted in Pennsylvania (18), Michigan (2, p. 6), and New York (5). This is less open to objection, and in hardwoods which sprout easily it may increase the natural food. It is expensive when done for deer alone, as are also all forms of artificial feeding (17, p. 34).

### *Predisposing Events*

*Predators.* We have found no record of a deer irruption in North America antedating the removal of deer predators. Those parts of the continent which still retain the native predators have reported no irruptions. This circumstantial evidence supports the surmise that removal of predators predisposes a deer herd to irruptive behavior.

In weighing this question, one must distinguish between the substantial removal of predators and the extirpation of the last individual.

Thus Wisconsin still has a dozen timber wolves, but wolves ceased to be a substantial factor in our deer herds a decade ago.

Wisconsin lost its last cougar in 1884 (24, p. 32). Wisconsin deer started to irrupt after wolves had been substantially removed.

Pennsylvania lost its last cougar in 1886 (25, p. 7), but both cougars and wolves had become too scarce to affect deer at a much earlier date. Bobcats were cut down to the vanishing point during the decade 1915-1925. Pennsylvania deer began irrupting about 1915.

In most parts of the west, the substantial extirpation of deer predators took place within a decade after 1910, when the present system of paid hunters came into full-scale operation. Thus on the Kaibab, wolves were a factor in 1910 but gone by 1926. Cougars were abundant up to about 1915; they are still present but are now kept reduced to a very low level (21, p. 236). The Kaibab deer irrupted almost immediately after the extirpation of wolves and the substantial removal of cougars. (See bottom of graph B, Figure 1.)

In Chihuahua, where deer are abundant and organized predator control unknown, irruptions are likewise unknown (15). No irruptions are clearly recorded for Canada, nor has government predator control prevailed there.

In Germany, deer were abundant in the feudal forests despite the presence of predators, but range or forest damage is not recorded until just before the Thirty Years War, when predator control had begun. Damage did not become severe until the last century, after the elimination of predators and the inauguration of artificial feeding (14).

Coyotes do not seem to be effective predators in the sense of controlling irruptions, for the Kaibab herd irrupted in the presence of numerous coyotes (21), and coyotes occur on the present irruptive ranges of Wisconsin and Michigan, as well as those of Utah, Oregon, New Mexico, California, and other western states.

It appears, then, that cougars and wolves are the most effective deer predators. The evidence available supports the surmise that their removal does not cause irruptions, but paves the way for irruptive behavior, either at once or at some future time.

*Cuttings.* It is common knowledge that in humid regions, where the original forests were so dense as to shade out browse, deer "followed the slashings," i.e., did not become abundant until after large areas had been converted to brush. Thus there were few or no deer around Lake Superior before the lumbering era (25, p. 119), and deer have spread north into Canada coincident with cuttings.

Here, too, a lag may occur. Thus Pennsylvania and southern New York were almost deerless for decades after slashings began. During this deerless lag exceedingly palatable plants, such as ground hemlock (*Taxus canadensis*) had a chance to accumulate. This stored reserve of very high-grade foods doubtless increased the violence of the later irruption.

In the open yellow pine forests and brushy foothills of the west, cuttings have no predisposing effect, for the original forests are open and can grow ample browse food.

*Current Cuttings.* Any winter cutting operation is likely to attract deer, which feed at night on the down tops felled by the loggers by day. The effect on deer depends on whether the cutting is continuous through the winter, and whether it makes available palatable trees capable of sustaining deer, or unpalatable ones on which deer starve despite full stomachs.

Cuttings are often interrupted by weather, or are discontinued in midwinter. In such event the whole dependent herd must starve suddenly unless natural browse is available. Such "trapped" herds seldom move.

A small cutting operation may "bait" a large deer herd, and keep it localized without actually feeding it enough tops to sustain life. In such event the dependent herd slowly starves.

Any cutting operating may safely feed a herd which is not too large for it, for the actual duration of continuous cuttings.

By and large, current cuttings have tended to postpone and exaggerate the penalties for excess deer. The present war demand for yellow birch and white cedar is feeding many deer which will be left foodless when the supply of these trees is exhausted, or when the demand for birch veneer and cedar posts falls off.

*Buck Laws.* Laws protecting antlerless deer predispose a herd to irruptive behavior to the extent that they are enforced, for the killing of males in a polygamous species has, within ordinary limits, no effect on reproductive rate.

By a strange irony, conservation departments in buck-law states, when they have failed to reduce their own does by legal means, have unwittingly delegated this important biological function to the law-violator, for the public begins to condone illegal doe-killing as excess numbers of does become visible. But for illegal doe-killing, many buck-law states would have irrupted earlier.

Buck laws are admirable for a herd which needs building up (20), but hardly for a herd in need of reduction. Irruptions have been confined to buck-law states, except in Minnesota where large refuges have shown irruptive effects. These large refuges have the same local effect as buck laws.

### *Other Factors*

*Fire.* There is general agreement that a little fire improves deer range, but that wholesale burning destroys it (1, p. 10). When deer happen to irrupt a decade or two after the first effective fire control, damage to deer and range is exaggerated by the closure of tree crowns, for this shades out much browse at a time of maximum need for browse. The present deer crisis in Wisconsin is exaggerated by the present closure of tree crowns which grew up following the fire-control system established about 1930.

In parts of the west, there was widespread reproduction of forest trees following early overgrazing and later fire-control. These new forests have now closed their crowns, and thus shaded out much browse (13).

### *Irruption Sequence*

These common characters of irruptive deer herds follow a sequence, the early stages of which are substantially alike for all herds, but the later stages of which differ according to whether remedial action is prompt and decisive, or dilatory and insufficient.

*Stage 1: Setting the Stage.* The combination of a buck law, a refuge system, good law enforcement, and predator removal "sets the stage" for irruption. In humid regions, widespread logging and some (but not too much) fire is further conducive to irruptive population behavior.

*Stage 2: Early Upgrade.* A deer-line appears on palatable browse, but the deer are still normal in growth, and winter well.

*Stage 3: Later Upgrade.* A deer-line appears on unpalatable browse, such as balsam. Fawns begin to die every hard winter, but adult deer do not. The stomachs of these fawns contain unpalatable (non-nutritious) browse; their lungs are commonly pneumonic. At this stage conifer plantations begin to show deer-damage, and reproduction of palatable browse has ceased to survive.

If the herd is sufficiently reduced at this stage, a considerable part of the overbrowsed palatable plants may recover, and a corresponding fraction of the pre-irruption carrying capacity is salvaged (George Reserve).

If the herd is not reduced it proceeds to:

*Stage 4: The Peak.* The peak of an irruption which has been allowed to run its course is always sharp (Kaibab).

The peak of an irruption which has been treated is rounded to the extent the herd has been reduced (Pennsylvania).

*Stage 5: Early Downgrade.* The downgrade begins when either starvation or shooting removes does as well as the annual fawn crop. Death of fawns alone fails to check increase, because some fawns always get by on logging operations or other extra-favorable winter range. Downgrade by starvation always begins during a hard winter.

By this time palatable browse, weakened during stages 2-4, begins to die off.

The deer at this stage show light weight and small antlers. Even the summer range may show distress.

*Stage 6: Late Downgrade.* This occurs only in starved herds. It is marked by continued starvation, due to the fact that the browse shrinks faster than the deer.

*Stage 7: Levelling off.* This marks the new equilibrium between the starved-off herd and its depleted food supply. A starved herd may stay level for decades, and that level is always lower than the pre-irruption carrying capacity. A herd which has been shot down levels off according to the promptness and decisiveness of the reduction. The sooner and greater the reduction, the higher the ultimate level.

This is why an irruption jeopardizes the future as well as the present welfare of a herd.

This Committee has not made a field study of the present Wisconsin irruption, but the Conservation Department has, and its findings are shortly to be published. The evidence gathered by the Department indicates that most northern Wisconsin counties, and some central Wisconsin counties, are now in Stage 3. If this is correct, there is imperative need for prompt and decisive herd-reduction in the irruptive counties.

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## PROCEEDINGS OF THE ACADEMY

### SEVENTY-THIRD ANNUAL MEETING

The seventy-third annual meeting of the Academy was held in Science Hall at Marquette University, Milwaukee, Wisconsin on Friday and Saturday, April 16 and 17, 1943. Three other organizations participated jointly in the meeting,—the Wisconsin Archeological Society, Wisconsin Museums Conference, and the Wisconsin Folklore Society. The Academy section met in Room 100, Science Building while the other sections held meetings in Room 200, Science Building. Approxmately 100 persons attended the various meetings. The annual business meeting and election of officers was held on Friday afternoon. The following program of papers was presented.

### ACADEMY SECTION

Friday afternoon

Walter D. Kline, Milwaukee Public Museum (Introduced by Ira Edwards), Lincoln's New Salem; J. F. Groves, Ripon College, Report Progress on Museum Work at Ripon College; Aldo Leopold, Ernest F. Bean, and Norman C. Fassett, University of Wisconsin, Deer Irruptions; (Report of the Conservation Committee of the Academy); H. A. Schuette, University of Wisconsin, Caricature and Cartoon in the Crusade for Pure Foods; A. W. Schorger, Burgess Cellulose Company, Lignocellulose Plastics; Lyle B. Hoskins and John R. Koch, Marquette University (Introduced by W. N. Steil), Structure of Cyclopentadiene Resins; James C. Perry, Marquette University (Introduced by W. N. Steil), The Role of Adrenalin in Vertebrate Reproduction; Rev. Francis J. Bloodgood, Madison, St. Thomas Aquinas; E. M. Gilbert, University of Wisconsin, Report of the Committee on the Junior Academy; Elizabeth A. Badalik, Maryville College, Blood Plasma (By title); Julia Graces Wales, University of Wisconsin, Professor Beatty's Interpretation of Shakespeare (By title).

### MUSEUMS-FOLKLORE-ARCHEOLOGICAL SECTION

Friday afternoon

Victor S. Taylor, Lake Mills, The Aztalan Museum; W. E. Dickinson, Milwaukee, Insect Superstitions; Rev. Peter Leo Johnson, St. Francis, On Ghost Churches; Albert Schnabel, Milwaukee, Desirable Accessions for Historical Museums; Dorothy Moulding Brown, Madison, Tisanes of Our Grandmothers; Charlotte R. Partridge, Milwaukee, Educational Work of the Layton Art Gallery; Will F. Bauchle, Beloit, A Century of Progress, Luther Valley; Mary M. Vandenburgh, Milwaukee, Indian Handicraft; Walter Bubbert, Milwaukee, Washington County German Place Names.

ACADEMY SECTION

Saturday morning

Ella M. Hanawalt, Milwaukee-Downer College, A School Visitation Project—An Experiment in the Education of Teachers; Louise S. Eby, Milwaukee-Downer College (Introduced by Ella M. Hanawalt), Towards a Scientific Method in Ethics; Ernest A. Bellis and Herbert Heinrich, Marquette University (Introduced by W. N. Steil), The Fatty Acids derived from Hydrogenated Castor Oil; Katherine F. Greacen, Milwaukee-Downer College, and John R. Ball (Introduced by W. N. Steil), Studies of Silurian Fossils in the Thomas A. Greene Collection at Milwaukee-Downer College; Emil P. Kruschke, Milwaukee Public Museum, Preliminary Report on the Flora of Wisconsin, XXXI. BORAGINACEAE (By title); E. S. McDonough, Marquette University, Notes on the Cytology and Host-parasite Relations of *Schlerospora*; Mary A. Tingley, Milwaukee-Downer College (Introduced by W. N. Steil), Studies on the Concentration of Plant Exudates; Edward Schneberger and L. A. Woodbury, Wisconsin Conservation Department, The Lake Sturgeon, *Acipenser fulvescens* Rafinesque, in Lake Winnebago, Wisconsin—Creel Census, Food and Growth; C. William Threinen and A. D. Hasler, University of Wisconsin, Studies of the Winter Perch Population in Lake Mendota; Chancey Juday, University of Wisconsin, The Photosynthetic Activities of the Plants of Little John Lake; Raymond H. Reis, S. J., Marquette University (Introduced by W. N. Steil), Change of Form in Pelmatohydra oligactis; Lowell E. Noland, University of Wisconsin, Laboratory Studies on the Biology of *Lymnaea Stagnalis appressa*; Leon J. Cole and Richard M. Shackleford, University of Wisconsin, Hybrids of Common and Arctic Foxes; Kenneth MacArthur, Milwaukee Public Museum, Occurrence of the Black Widow Spider and Tropical Rat Mite in Wisconsin; Loyal Durand, Jr., University of Wisconsin, A Brief History of the Wisconsin Academy of Sciences, Arts and Letters.

MUSEUMS-FOLKLORE-ARCHEOLOGICAL SECTION

Saturday morning

Theodore Mueller, Milwaukee, Origin of the Songs of the Turners; Albert O. Barton, Madison, The Black Hawk War in Dane County; Phebe Jewell Nichols, Shawano, Wisconsin, What Does It Mean?; Hans D. Gaebler, Watertown, The Story of the Five Coffins; Edith Stratton Colbo, Racine, A Racine County Park of Statewide Interest; Allie Freeman, Horicon, Dodge County Irish Folklore; Newell E. Collins, Algonac, Michigan, Perforated Indian Skulls; Marvel Ings, Madison, Educational Services of the State Historical Museum; J. Stanley Dietz, Madison, Civil War Battleflags; Nancy D. Oestreich, Milwaukee, Indian Lore for Camp and School; Helene Stratman-Thomas, Madison, Wisconsin History in Song; Sheldon T. Gardner, Viroqua, Paul Bunyan and the Wisconsin Dells; Vivien G. Dube, Superior, Indian Legends of the North Shore; Robert Newman, Eau Claire, Bluenose Brainerd Tales; Albert H. Griffity, Oshkosh, Lincoln Literature; George Overton, Butte des Morts, Indian

Laws; Charles E. Brown, Madison, Log Cabin and Log Camp Museums of Wisconsin.

## ANNUAL ACADEMY LECTURE

The annual Academy dinner was held on Friday evening April 16, in Room 100, Science Building. Two addresses were made. President A. W. Schorger of Madison presented his presidential talk, the title of which was "Science and Individualism." Professor Karl P. Link of the University gave an illustrated talk on "From the Haystack to the Clinic."