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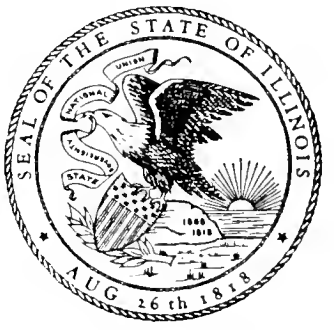

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SKRJABINGYLUS CHITWOODORUM (NEMATODA: METASTRONGYLIDAE) IN SKUNKS IN ILLINOIS

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Skrjabingylus chitwoodorum has been found in the frontal sinuses of skunks in several localities in the United States, but it has not heretofore been reported from Illinois. The purpose of the present paper is to record its occurrence in this state and to summarize earlier reports on its occurrence, life cycle and pathogenesis.

In connection with a study of sylvan rabies, the brains of 184 striped skunks (*Mephitis mephitis*) from northern Illinois were examined. *Skrjabingylus chitwoodorum* was found in the sulci and fissures beneath the dura mater in two of these animals. Two male and two female nematodes were found in an adult male skunk trapped March 19, 1958 in Carroll County, Illinois, and two males and two females were found in another adult male skunk trapped June 24, 1958 in Cook County.

In addition to the above, a single male *S. chitwoodorum* was found February 23, 1959 on the brain of a road-killed male skunk near Pomona, Jackson County, and a single female nematode was found on the brain of a female skunk caught in a trap March 11, 1959 by a fox trapper near Alto Pass, Union County. Both these counties are in southern Illinois.

All the worms were not intact, so that it was not possible to make complete measurements. Three females were 27 to 42 mm long and 842 to 1070 microns wide. Five males were 16 to 24 mm long and 502 to 816 microns wide. The spicules of four males were 800, 816, 846 and 875 microns long, respectively, and the gubernacula of two males were 90 and 97 microns long. These may be compared with spicule lengths of 540 to 710 (average 631) microns reported by Hill (1939) and of 715, 795 and 830 microns reported by Goble (1942), and to gubernaculum lengths of 72 to 88 (average 80) microns reported by Hill (1939).

Skrjabingylus chitwoodorum Hill, 1939 was originally described from two striped skunks, *Mephitis mephitis mesomelas* (syn., *M. mesomelas mesomelas*), and three eastern spotted skunks, *Spilogale putorius interrupta* (syn., *S. interrupta*), in Oklahoma by Hill, (1939). (The names of the hosts in our paper are those used by Hall and Kelson, 1959).

S. chitwoodorum has also been found in *Mephitis mephitis occidentalis* (syn., *M. occidentalis*) in California by Hobmaier (1941), in

[1] This study was supported in part by National Institutes of Health Grant E-1349.

18 of 25 *M. m. nigra* (syn., *M. nigra*) in New York by Goble (1942) and Goble and Cook (1942), in a dead skunk (presumably *M. mephitis*) in Pennsylvania by Bell and Chalgren (1943), and in *M. m. nigra,* presumably from the vicinity of Beltsville, Maryland by Dikmans and Goldberg (1949). In addition, Stegeman (1939) found bone lesions suggestive of *S. chitwoodorum* infection in the skulls of 26 out of more than 150 *M. m. nigra* from New York, and Tiner (1946) found similar lesions in the skulls of 3 *M. m. varians* out of 400 skulls of this species and *Spilogale g. gracilis* (syn., S. *leucoparia*) in Texas. Finally, Miller (1899) found nematodes which were identified as *Filaroides mustelarum* but which were undoubtedly *S. chitwoodorum* in the frontal region of the skulls of skunks (*M. m. mephitis*) at North Bay, Ontario, and stated that all the adult skunks which he took in this area were infected.

The only record of *S. chitwoodorum* in *Spilogale putorius* is that of Hill (1939) in Oklahoma.

S. chitwoodorum has been found in the western spotted skunk, *S. gracilis,* in California by Grinnell, Dixon and Linsdale (1937), in *S. gracilis phenax* in California by Hobmaier (1941), and in *S. gracilis latifrons* in British Columbia by Cowan (1941). In addition, Tiner (1946) found bone lesions suggestive of *S. chitwoodorum* infection in the skulls of 3 *S. g. gracilis* (syn., *S. leucoparia*) out of 400 skulls of this species and *M. m. varians* in Texas.

Hobmaier (1941) found that third stage larvae developed in slugs and snails. Development was best in *Limax maximus, L. cinereus, L. flavus, L. niger, Agriolimax agrestis* and *Milax* sp., while *Epiphragmophora* sp. and *Helix pomatia* were seemingly less favorable hosts. Hobmaier apparently infected skunks with larvae from slugs or snails. In addition, he found a natural infection with third stage larvae in a Pacific garter snake, *Thamnophis sirtalis infernalis,* and he infected frogs artificially. He was unable to obtain adult nematodes in artificially exposed guinea pigs, dogs, cats or ferrets, but found some larvae in the stomach wall and mesenteries of mice and rats. He considered that the normal route of migration of the larvae in skunks was directly from the mouth thru the nasal passages to the sinuses.

S. chitwoodorum ordinarily occurs in the frontal sinuses and may deform the skull. Bell and Chalgren (1943) stated that the skunk which they examined "had bulbous enlargments of the frontal sinuses containing" the nematode. Miller (1899) reported that the parasites he found disfigured the frontal region of the skulls of a large proportion of the specimens. Stegeman (1939) found that 26 of more than 150 skulls of skunks from New York had a porous, relatively soft, frequently discolored dilation on the dorsal surface at the junction of the frontal and parietal bones; the cavities in these swellings were continuous with the frontal sinuses; he found no worms, since he was studying skulls alone. The lesions which Tiner (1946) found in the skulls of *S. gracilis* and *M. mephitis* and which he assumed were caused by *S. chitwoodorum* varied from marked

bulging and osteitis over the frontal sinuses to actual holes in the walls of one or both of them.

Lesions suggestive of *S. chitwoodorum* infection were seen in the frontal region of the skull of a fifth skunk collected in northern Illinois; the frontal sinuses of this animal were not examined, and no worms were seen. However, no lesions were seen in the skulls or brains of the Illinois skunks in which *S. chitwoodorum* was found. Our report is apparently the first record of this nematode's occurrence in the brain cavity.

Summary

Skrjabingylus chitwoodorum was found in the sulci and fissures of the brain beneath the dura mater of 2 out of 184 striped skunks (*Mephitis mephitis*) in northern Illinois and in 2 other *M. mephitis* in southern Illinois. This is apparently the first record of this nematode's occurrence in the brain cavity. The hosts were apparently healthy, and their skulls were not noticeably deformed. Earlier reports on *S. chitwoodorum* are summarized.

Literature Cited

Bell, J. F., and W. S. Chalgren. 1943. Some wildlife diseases in the eastern United States. J. Wildlife Manag., 7: 270-278.

Cowan, I. McT. 1941. Report upon some diseases and parasites of game birds and game and fur-bearing mammals in British Columbia. Rep. Prov. Game Comm. Brit. Col., 40-45.

Dikmans, G., and A. Goldberg. 1949. A note on *Arthrocephalus lotoris* (Schwartz, 1925) Chandler, 1942 and other roundworm parasites of the skunk, *Mephitis nigra*. Proc. Helm. Soc. Wash., 16: 9-11.

Goble, F. C. 1942. *Skrjabingylus chitwoodorum* from the frontal sinuses of *Mephitis nigra* in New York. J. Mammal., 23: 96-97.

Goble, F. C., and A. H. Cook. 1942. Notes on nematodes from the lungs and frontal sinuses of New York fur bearers. J. Parasitol., 28: 451-455.

Grinnell, J., J. S. Dixon and J. M. Linsdale. 1937. Fur-bearing mammals of California. 310 pp.

Hall, E. R., and K. R. Kelson. 1959. The mammals of North America. Vol. II. New York, Ronald Press Co., 1083 pp.

Hill, W. C. 1939. The nematode *Skrjabingylus chitwoodorum* n. sp. from the skunk. J. Parasitol., 25: 475-478.

Hobmaier, M. 1941. Extramammalian phase of *Skrjabingylus chitwoodorum* (Nematode. J. Parasitol., 27: 237-239.

Miller G. S., Jr. 1899. Notes on the mammals of Ontario. Proc. Boston Soc. Nat. Hist., 28: 1-44.

Stegeman, L. C. 1939. Some parasites and pathological conditions of the skunk (*Mephitis mephitis nigra*) in central New York State. J. Mammal., 20: 493-496.

Tiner, J. D. 1946. Some helminth parasites of skunks in Texas. J. Mammal., 27:82-83.

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ADDITIONAL FAUNAL RECORDS FROM THE KINGSTON LAKE SITE, ILLINOIS

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Recent acquisitions by the Illinois State Museum of private archaeological collections from the Kingston Lake (Village; Kitchen Midden) Site has provided quantities of bone and shell of noteworthy interest. Recovery of this material was made periodically from 1932 to about 1943, and through the kindness of Mr. L. P. Elliott, Dr. V. H. Chase and the late Dr. Donald E. Wray, all of Peoria, animal remains found by them at this site were made available for study. A small sample of bone collected by the late George and Ethel Schoenbeck during this time period has also been included in this report.

This large Middle Mississippi site (primarily Spoon River Focus: 1,100-1,400 A.D.), once covering approximately 15 acres, was situated on the north bank of Kingston Lake (parallel and adjacent to the Illinois River) 15 miles southwest of Peoria, Peoria County, Illinois. The village and the one large platform mound were the property of the Kingston Lake Gravel Company, and with the commencing of dredging operations in 1931, the site was gradually destroyed until, by 1938, most of it was gone. A general account of the artifacts, burials and other materials recovered during these years has been presented by Simpson (1939). Included in Simpson's report is an article by F. C. Baker on a sample of the faunal materials found at the beginning of the excavations; this same article appeared in the *Transactions of the Illinois Academy of Science* (Baker, 1936). A few of the first specimens recovered from this site ("Simpson Village") were reported in an earlier paper by Baker (1931).

The variety of both molluscan and vertebrate species represented provides an excellent index of the food habits of these people as well as to the prehistoric distribution and possible abundance of the local fauna. As suggested by the remains of certain species, both the marshy floodplain areas to the south and upland areas to the north were hunted for game. As evidenced by the variety of fresh-water mussels, fish, turtles, and aquatic and semi-aquatic species of birds and mammals, however, the Illinois River and its associated backwaters and bottomlands constituted the major areas hunted. The recently acquired faunal materials considered in this report add to the number of species previously recorded, as well as to the quantity, thus presenting a more complete study of the early fauna and its use by the Indians occupying this site. Table 1 is a list of the species identified from the Kingston Lake Site, including those recorded by Baker

(1931, 1936) and those recently obtained from Elliot, Chase and Wray.

Accounts of Species

Mollusks. — Compared with the quantity and variety of marine shells recovered at the Cahokia Site (Parmalee, 1958a), located along the Mississippi River (Madison Co., Illinois) and probably contemporaneous with this site, there was little evidence found to suggest a like use of such marine forms by the Kingston Lake people. Apparently trade routes or contacts with the southeastern coastal areas were meager, and the only reference to the use of marine shells states that "... several tools made from the columnella of conch shells ... were collected" (Simpson, 1939).

Fresh-water mussels, however, were used extensively for food and, to a lesser degree, for ornaments and/or implements. Twenty-four species were identified and nearly all were typical large-river forms. Simpson (*op. cit.*) mentions the finding of two "clam bakes" in which mussels had been placed in the ground for baking but never removed. Mussels were undoubtedly collected locally in the Illinois River beds; with the possible exceptions of *P. lineolata, O. olivaria* and *E. crassidens,* all species represented apparently still inhabit that section of the river. *Alasmidonta marginata* is a headwater or small-stream form and normally does not occur in a large river environment, and its presence with all large-river species is unusual.

Valves of mussels were used in the manufacture of beads, spoons, and hoes. Simpson (*op. cit.*) records two spoons (probably *L. ventricosa*?), 10 shell ornaments, 695 disc beads (possibly from marine whelks rather than mussels?) and 170 shell hoes, and states that "With two exceptions, all [hoes] were made from one species of clam." This would probably be the large, thick-shelled washboard, *M. gigantea*; 15 shell hoes in the Elliott collection were referable to this species.

Vertebrates. — Twenty species of mammals were identified from the Kingston Lake Site, bones of the white-tailed deer forming 65 percent of the total. Although the percentage of deer bone to that of other species was not so large as it is at most sites (*e.g.* Cahokia: Parmalee, 1957), the quantity of remains attest to the use of this animal as a basic meat staple. Numerous deer bone artifacts were recovered, including cut antler, antler tines and projectile points, awls (from ulnae and splinters), jaw bone "hoes" and beamers (from metatarsals).

Several species of the smaller mammals (raccoon, beaver, muskrat, cottontail, squirrel) were also taken in considerable numbers, their remains comprising 18 percent of the mammalian bone. Remains of the mole and small rodents (*Peromyscus, Citellus, Oryzomys*) are probably from animals that died naturally at the site location and were incidental to human occupation. However, as Baker (1936) has indicated, the former occurrence of the marsh rice rat in Peoria County is of special significance since it is now restricted to the southern most part of the state. This rodent has since been identified from several other sites in the Illinois-Mississippi river valley

(Parmalee, 1957) and its presence at these sites is indicative of dense vegetation along marsh and swamp margins.

Elk still inhabited the Illinois region in early historic times and bones have been recovered at numerous aboriginal village sites, but only rarely in any quantity. Apparently elk were far less numerous than the white-tailed deer in prehistoric times. One of the more interesting aspects of the mammalian complex from this site is the occurrence of bison. Griffin and Wray (1945) have suggested that this animal did not cross the Mississippi River into eastern United States until 1600 or shortly before. This appears correct as bison remains in prehistoric Illinois sites are typically rare or nonexistent; only in the historic components of the Starved Rock and Zimmerman sites in La Salle county have bison bones been encountered in quantity (over 150 specimens in the Illinois State Museum archaeozoological collections). The Schoenbecks reportedly obtained a scapula hoe "thought" to be bison from this site and, although the number of bones recovered are few, they may suggest a beginning of the eastward bison migration in the late 15th or early 16th century.

Birds were apparently an important source of food to these Indians, and the Illinois River, Kingston Lake and associated backwaters formed an excellent habitat for a large variety of species. At least 36 species were represented, and bones of waterfowl (ducks, geese, swans) comprised 54 per cent of the total identified birds. Other aquatic and semi-aquatic species (sora, cormorant, coot, shorebirds, *etc.*) formed an additional 12 percent. Only two species, the bobwhite and the prairie chicken, suggest an upland prairie habitat.

The trumpeter swan is now extirpated in Illinois. In prehistoric times, however, it was a common migrant along the Mississippi River and apparently, but to a lesser extent, elsewhere in the state, so remains of this species at the Kingston Lake Site are not unexpected. Although far less numerous than at Cahokia (Parmalee, 1957), bones of *O. buccinator* at this site establishes it as a former migrant through central Illinois. A single, cut distal humerus end was recovered at Kingston Lake; these cut ends were common at the Cahokia Site (Parmalee, *op. cit.*), the bone shaft having apparently been used for tools or sectioned into beads. The majority of the other avain species identified from this sample still occur locally or as migrants through the area. However, the wild turkey is now extirpated in Illinois and the prairie chicken is no longer found in that area. Both the whistling swan and sandhill crane occur rarely during migration, and the long-billed curlew (now accidental in Illinois) has been identified from only two other sites (Parmalee, 1958b; plus an historic Crawford Farm Site, Rock Island Co. record).

Turtles were utilized to a limited extent by the Indians who occupied this site, probably mainly for food, although sections of worked carapace (scraped interior) were recovered which indicate that shells were occasionally fashioned into bowls or dishes. A minimum of six

TABLE 1.—Enumeration of the Animal Species Identified from the Kingston Lake Site, Peoria Co., Illinois.

Species	Number of Specimens	
	Elliott, Chase, Wray, Schoenbeck	Baker (1931; 1936)
Fresh-water mussels		
Amblema peruviana (*rariplicata*), Blue-point	29	3
Megalonaias gigantea, Washboard	28	1
Actinonaias carinata, Mucket	20	6
Elliptio dilatatus, Spike	17	9
Fusconaia undata, Pig-toe	14	3
Quadrula pustulosa, Pimple-back	12	2
Elliptio crassidens, Elephant's Ear	10	1
Fusconaia ebenus, Niggerhead	7	1
Lampsilis ventricosa, Pocketbook	7	2
Lampsilis siliquoidea, Fat Mucket	5	2
Quadrula quadrula, Maple-leaf	5	1
Pleurobema (*cordatum*) *pyramidatum* and *P. c. coccineum*, Small Niggerhead	4	2
Proptera alata, Pink Heel-splitter	2	2
Plethobasus cyphyus, Bullhead	2	1
Ligumia recta, Black Sand-shell	2	1
Quadrula metanevra, Monkey-face	1	
Obovaria olivaria, Hickory-nut	1	
Tritogonia verrucosa, Buckhorn	1	
Quadrula nodulata, Warty-back	1	
Cyclonaias tuberculata, Purple Warty-back		1
Alasmidonta marginata, Elk-toe		1
Arcidens confragosus, Rock Pocketbook		1
Plagiola lineolata, Butterfly		1
Lampsilis fallaciosa, Slough Sand-shell		1
Snails		
Campeloma integrum	1	
Campeloma rufum		1
Pleurocera acuta		1
Fishes		
Bowfin, *Amia calva*	29	5
Fresh-water Drum, *Aplodinotus grunniens*	24	3
Channel and/or Blue Catfish, *Ictalurus* sp.	20	
Bullhead, *Ictalurus* (*Ameiurus*) sp.	19	3
Suckers and Buffalofish, Catostomidae	18	
Buffalofish, *Ictiobus* sp.	10	
Gar, *Lepisosteus* sp.	7	
Longnose Gar, *Lepisosteus osseus*	3	2
Pike, *Esox* sp.	3	
Northern Pike, *Esox lucius*	2	
Redhorse, *Moxostoma* sp.	2	
Bass, *Micropterus* sp.	1	1
Sturgeon, *Scaphirhynchus* sp.?	1	
Flathead Catfish, *Pylodictis olivaris*	1	
Smallmouth Buffalofish, *Ictiobus bubalus*		14+
Turtles		
Box Turtle, *Terrapene* sp.	31	
Soft-shelled Turtle, *Trionyx* (*Amyda*) sp.	26	1
Turtle spp.	20	
Pond Terrapin, *Pseudemys scripta*	12	
Turtle, *Pseudemys*, *Graptemys*, *Chrysemys* group	8	4
Snapping Turtle, *Chelydra serpentina*	1	
Map Turtle, *Graptemys geographica*	1	
Blanding's Turtle, *Emys blandingii*	1	

Birds		
Mallard, *Anas platyrhynchos*, and/or Black Duck, *A. rubripes*	25	3
Turkey, *Meleagris gallopavo*	17	7
Canada Goose, *Branta canadensis*	11	2
Prairie Chicken, *Tympanuchus cupido*	10	5
Duck spp.	7	
American Coot, *Fulica americana*	5	2
Trumpeter Swan, *Olor buccinator*	5	2
Wood Duck, *Aix sponsa*	5	1
Bobwhite, *Colinus virginianus*	4	2
Redwinged Blackbird, *Agelaius phoeniceus*	4	1
Green-winged Teal, *Anas carolinensis*	4	1
Bufflehead, *Bucephala albeola*	3	2
Lesser Scaup, *Aythya affinis*, and/or Ring-necked Duck, *A. collaris*	2	3
Canvasback, *Aythya valisineria*	2	2
Blue-winged Teal, *Anas discors*	2	3
Long-billed Curlew, *Numenius americanus*	2	1
Sora, *Porzana carolina*	2	2
Snow and/or Blue Goose, *Chen sp.*	2	
Pintail, *Anas acuta*	2	1
Flicker, *Colaptes* cf. *auratus*	1	1
Blue Jay, *Cyanocitta cristata*	1	
Rusty Blackbird, *Euphagus carolinus?*	1	
Sparrow Hawk, *Falco sparverius*	1	
Double-crested Cormorant, *Phalacrocorax auritus*	1	
Black-crowned Night Heron, *Nycticorax nycticorax*	1	2
Whistling Swan, *Olor columbianus*		2
Hooded Merganser, *Lophodytes cucullatus*		2
Bald Eagle, *Haliaeetus leucocephalus*		2
American Bittern, *Botaurus lentiginosus*		1
Red-tailed Hawk, *Buteo jamaicensis*		1
Red-shouldered Hawk, *Buteo lineatus*		1
Broad-winged Hawk, *Buteo platypterus*		1
Sandhill Crane, *Grus canadensis*		1
Woodcock, *Philohela minor*		1
Short-billed Dowitcher, *Limnodromus griseus*		1
Shoveller, *Spatula clypeata*		1
Grackle, *Quiscalus quiscula*		1
Mammals		
White-tailed Deer, *Odocoileus virginianus*	404	6+
Beaver, *Castor canadensis*	37	8+
Raccoon, *Procyon lotor*	25	2
Elk, *Cervus canadensis*	24	1
Canids: *Canis* sp., and Dog, *C. familiaris*	22	13+
Muskrat, *Ondatra zibethica*	17	7
Cottontail, *Sylvilagus floridanus*	13	2
Fox Squirrel, *Sciurus niger*	12	4
Mink, *Mustela vison*	4	6+
Bison, *Bison bison*	4	
Bobcat, *Lynx rufus*	2	1(?)
Gray Squirrel, *Sciurus carolinensis*	2	1
Striped Skunk, *Mephitis mephitis*	2	
Franklin Ground Squirrel, *Citellus franklinii*	2	
Marsh Rice Rat, *Oryzomys palustris*	1	3
River Otter, *Lutra canadensis*	1	1
Gray Wolf, *Canis lupus*	1	
Opossum, *Didelphis marsupialis*	1	
Common Mole, *Scalopus aquaticus*		2
White-footed Mouse, *Peromyscus* cf. *leucopus*		1

species were determined, and 69 percent of the remains were those of aquatic forms. With the possible exception of *Emys blandingii*, all of the turtles represented are still common in that area.

Fish were well represented in the general midden deposit and in refuse pits, with at least 12 species being identified. Judging from the size of many specimens, and from the species involved, most of the fish were taken in the Illinois River. Remains of the bowfin were the most numerous (29), while bones of several species of other "rough fish," the gar and catastomids, comprised 33 percent of the total. Catfish and bullheads were taken in considerable numbers, while drum ranked second in the number of bones recovered; compared with specimens of known weight, the majority of drum caught by these Indians weighed between 6 and 10 pounds. Considering the large size of many of the drum, catfish and buffalofish, fish were an important source of food to these people.

Apparently few "game fish" were caught by the Indian as evidenced by paucity of remains. In addition to the bass and pike listed in Table 1, Simpson (1939) mentions many crappie (*Pomoxis* sp.) scales found in a grave fill (identified by Dr. D. F. Hansen, Dept of Zool., U. of I., Urbana). Through the courtesy of Dr. Donald F. Hoffmeister, Director of the Museum of Natural History, University of Illinois, Urbana, the author was able to examine the faunal specimens described by Baker (1936). One apparent error is the identification of a dentary as *Stizostedion*; this jaw section appears to be *Esox* rather than sauger or walleye. The presence of northern pike at this site is noteworthy since this fish is now restricted (except where re-introduced) in Illinois to the northern sections of the Mississippi River. Two large jaw sections of the pike recovered by Mr. Elliott were from fish that weighed 6 to 8 pounds. Parts of three smaller mandibles are also probably *E. lucius*, but may be referable to the redfin pickerel, *E. americanus*.

Summary

Faunal remains recovered at the Kingston Lake Site in Peoria County, Illinois, between 1932 and 1943 were discussed. A minimum of 12 species of fish, 6 species of turtles, 36 species of birds and 20 species of mammals were identified, the majority of which still occur in the region. Several, such as the bison, elk, otter, gray wolf, turkey, and trumpeter swan, are now extirpated in Illinois while the prairie chicken, long-billed curlew, bobcat, white-tailed deer and marsh rice rat are no longer present locally. Extensive river and bottomland habitat provided a variety of game species which were utilized by the Indian. Freshwater mussels were also important food items, and 24 species were identified from this site.

Literature Cited

Baker, Frank C. 1931. Additional notes on animal life associated with the mound builders of Illinois. Trans. Ill. Acad. Sci., 23: 231-235.

Baker, Frank C. 1936. Remains of animal life from the Kingston kitchen midden site near Peoria, Illinois. Trans. Ill. Acad. Sci., 29:243-246.

GRIFFIN, JOHN W., and DONALD E. WRAY. 1945. Bison in Illinois archaeology. Trans. Ill. Acad. Sci., 38: 21-26.

PARMALEE, PAUL W. 1957. Vertebrate remains from the Cahokia site, Ill. Trans. Ill. Acad. Sci., 50: 235-242.

PARMALEE, PAUL W. 1958a. Marine shells of Illinois Indian sites. Nautilus, 71(4): 132-139.

PARMALEE, PAUL W. 1958b. Remains of rare and extinct birds from Illinois Indian sites. Auk, 75(2): 169-176.

SIMPSON, A. M. 1939. The Kingston village site. Peoria Acad. Sci., Arch. Sect., 15 pp.

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RESPONSE OF BOBWHITE QUAIL TO MANAGEMENT ON SOME ILLINOIS STRIP-MINED LANDS

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Population changes of bobwhite quail, *Colinus virginianus*, in response to habitat development on strip-mined lands have been studied in southern Illinois since 1954. This has been conducted as a part of a cooperative research project to evaluate the potential of spoil banks as recreational areas with primary emphasis on hunting and fishing. Initially, population levels of bobwhites precluded productive hunting on stripmine lands and it was considered important to determine the feasibility of developing such areas to increase resident game populations. Earlier efforts toward reclamation on strip-mined lands have most often been directed toward forestry, horticultural and grazing practices (Klimstra, 1959).

Acknowledgments

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Description of Area

A 920-acre tract, located 6 miles south of Pinckneyville and 3 miles west of Pyatts, Perry County, Illinois was deeded to Southern Illinois University for research purposes by the Truax-Traer Coal Company. Small agricultural fields interspersed with woods border on the west and partially on the south; similar striplands lie adjacent to all other boundaries.

The spoilbanks on the research area, formed from 1932 through 1941 (excluding 1934), vary in direction, length and height. Erosion has rounded the crests and deposited alluvial materials in the valleys between the ridges. Soils, at or near the surface, generally have sufficient quantities of available phosphorus and potash; nitrogen is available at the rate of 30 to 40 pounds per acre (Birkenholz, 1958). Except for shale and gob deposits, soils are neutral or basic. Analysis of soils and vegetation indicate that soil fertility is better than adjacent farm lands not under proper management (Klimstra, 1959).

Approximately one-half of the total area, including the south and western portions, was planted to trees in 1942 and 1943. Pine planta-

tions contain short-leaf pine (*Pinus echinata*) and jack pine (*Pinus banksiana*); deciduous species include black locust, osage-orange (*Maclura pomifera*), catalpa (*Catalpa speciosa*), silver maple (*Acer saccharinum*) and oaks (*Quercus* spp.). Excluding the black locust plantings, these plantations, characterized by a dense stand of trees and sparse understory, are of little value to upland game and require extensive management to produce suitable habitat.

The main herbaceous species (scientific nomenclature after Jones, 1950) on naturally revegetated spoilbanks include sweetclover (*Melilotus alba* and *M. Officinalis*), goldenrod (*Solidago* spp.), woody aster (*Aster pilosus*) and cheat (*Bromus secalinus*). Interspersed widely with these herbs are clumps of sumac (*Rhus glabra* and *R. copallina*), poison ivy (*Rhus radicans*) and blackberry (*Rubus frondosus*). Cottonwood (*Populus deltoides*), sycamore (*Plantanus occidentalis*), willow (*Salix interior*), elm, (*Ulmus rubra*), box elder (*Acer negundo*) and persimmon (*Diospyros virginiana*) are common trees.

Previous studies (Brewer and Triner, 1956; Verts, 1957) showed that the vegetation in the naturally revegetated areas is similar in each age group of spoils; species composition, number of stems, average height of vegetation, and percentage of bare ground varies little from areas mined in 1932 to spoilbanks formed in 1941. The only significant difference in the vegetation on the oldest spoils as compared with those more recently formed is the increase in diameter and height of the trees.

Typical of many Southern Illinois strip-mined areas, there are two unmined tracts on this research area. A 51-acre plot near the center and a smaller one along the west border provide about 60 acres of tillable land though the clay soils are of low fertility and poorly drained.

On the basis of initial studies (Brewer and Triner, 1956; Verts, 1956) it was believed that spoilbank habitat could be improved for upland game. The uniformity of vegetative cover as well as the lack of it in some areas, the absence of plant species which provide food, and the lack of openings or breaks in plant distribution were considered major limiting factors.

Techniques

Roads, totaling 4.2 miles in length, were constructed. A total of 12.1 miles of spoil crests were leveled; 0.9 mile of spoil valley was graded and widened. Selected areas of spoilbanks were leveled to provide plots ranging from 0.25 acre to 1.5 acres in size. These developments not only created critically needed "edge" but also bare ground for establishing plant species which would benefit bobwhites.

Korean lespedeza (*Lespedeza stipulacea*) was broadcasted on roadsides, leveled areas, non-mined lands and spoilbanks lacking in ground cover each winter after 1955. Establishment has been successful on over 100 acres of the research area; natural reseeding occurs each year.

Sericea and bicolor lespedezas (*Lespedeza sericea* and *bicolor*) were planted on spoils, roadsides and in prepared food plots. Food patches

containing combinations of Korean lespedeza, German millet (*Setaria italica*), sorghum (*Sorghum vulgare*), soybeans (*Glycine max*), corn (*Zea mays*) and buckwheat (*Fagopyrum esculentum*) were established on the unmined areas and in spoilbanks on leveled areas. Row crops were planted most years on the interior and perimeter areas that were not mined.

Since 1954, quail populations have been censused each year just prior to the hunting season (Table 1); in addition, daily observations of coveys have been maintained. Except for 1958, censuses were accomplished in 2 or 3 days by 5 to 12 persons walking abreast along the crests of adjacent spoilbanks. Dogs were utilized where possible, but dense patches of briars and the undulating terrain restricted their effectiveness. The fall population in 1958 was estimated on the basis of the number of quail present the following spring.

Crops were obtained from 49 quail harvested from November 14 to December 23, 1959, on the research area. Food items from the crops were identified and compared with contents from crops of six quail collected during the fall of 1955.

Presentation and Analysis of Data

The number of bobwhites on the research area (Table 1) increased from 46 birds in 1954 to 279 in the fall of 1959. The population nearly doubled from 1954 to 1955 and from 1955 to 1956; increase was more gradual in subsequent years. The population buildup continued on the research area through 1958 and 1959 despite decreases in regional populations (Klimstra, 1958, 1959).

Table 1.—Bobwhite Quail Populations on the Pyatts Striplands Research Area, November, 1954-59.

Year	Number of Coveys	Mean Covey Size	Total Number of Quail
1954...	4	11.5	46
1955...	7	12.0	84
1956...	10	16.3	163
1957...	12	13.9	167
1958...	16*	13.5*	216*
1959...	20	13.9	279

* Estimated on basis of prenesting population and routine field observations.

Excluding the pine and hardwood plantations not used by quail, the population density was about one bird per 2.3 acres of habitat after 4 years of management; nearly 250% more than on unmanaged farm lands in southern Illinois (Klimstra, 1959). This increase in population, when compared with adjacent unmanaged, but similar, spoilbank areas, is striking. The high population level afforded hunting in 1959 even though the terrain was more difficult to traverse than nonmined areas.

Roads and leveled crests of spoils were important in both management and hunting of quail. The roads were valuable to quail as loafing sites when vegetation was wet and in providing edge. Food plots were developed adjacent to roads and leveled crests of spoils to facilitate access for management and hunting. Quail did not include in their ranges areas where there had been extensive leveling of spoils or the isolated

leveled plots when no food producing plants were provided. Regrowth of sweetclover, briars, cottonwoods, and cheat was more rapid on these cleared and unplanted areas than on areas planted to favorable plant species following disturbance of the natural vegetation.

With the exception of black locust plantings, tree plantations were of little value as quail habitat at any time during the year. The open canopy resulting from destruction by the locust borer on the trees produced an understory vegetation. With food available from the locust and cover from the tangled understory, quail utilized segments of the locust plantations; however, hunting was next to impossible because of the dense growth. Large plantation plantings (exceeding 5 acres in size) are not recommended for spoilbanks which are managed for wildlife. Limited pine plantings may be used to enhance aesthetic qualities of striplands and to provide edge, but large block plantings offer little food or protection for bobwhites.

TABLE 2.—Food Items Identified from Crops of Bobwhite Quail Collected on the Pyatts Stripland Research Area, Fall, 1959.

Food Item	1959		
	Per cent occurrence	49 crops Rank	Per cent volume
Korean lespedeza (*Lespedeza stipulaceae*)	94.0	1	73.0
Common lespedeza (*Lespedeza striata*)	26.0	2	trace
German millet (*Setaria italica*)	24.0	3	17.4
Sweet clover (*Melilotus* spp.)	20.0	4	trace
Small wild bean (*Strophostyles leiosperma*)	18.0	5	trace
Common ragweed (*Ambrosia elatior*)	16.0	6	trace
Tick-clover (*Desmodium* spp.)	16.0	6	1.2
Lance-leafed ragweed (*Ambrosia bidentata*)	14.0	7	trace
Dwarf sumac (*Rhus copallina*)	12.0	8	1.2
Trailing wild bean (*Strophostyles helvola*)	8.0	9	trace
Beggar-ticks (*Bidens* spp.)	8.0	9	trace
Wild black cherry (*Prunus serotina*)	8.0	9	1.2
Grit	8.0	9	trace
Short horned grasshopper (*Locustidae*)	6.0	10	trace
Cheat (*Bromus secalinus*)	6.0	10	trace

TABLE 2.—Continued.

Food Item	1959		
	Per cent occurrence	49 crops Rank	Per cent volume
Pennsylvania smartweed (*Polygonum pennsylvanicum*)	6.0	10	trace
Leafy material	6.0	10	trace
Hemiptera (*Redviidae*)	6.0	10	trace
Sorghum (*Sorghum vulgare*)	4.0	11	trace
Partridge-pea (*Cassia fasciculata*)	4.0	11	trace
Leaf beetles (*Chrysomelidae*)	4.0	11	trace
Soybeans (*Glycine max*)	2.0	12	trace
Smooth sumac (*Rhus glabra*)	2.0	12	trace
Black locust (*Robina pseudoacacia*)	2.0	12	2.5
Rough buttonweed (*Dioda teres*)	2.0	12	trace
Panic grass (*Panicum* spp.)	2.0	12	trace
Paspalum spp.	2.0	12	trace
Yellow foxtail (*Setaria lutescens*)	2.0	12	trace
Spiders (Arachnidae)	2.0	12	trace
Total Number of Food Items	29		

Thinning and block cutting (or using chemical herbicides) within plantations might enhance their wildlife values, but are expensive and time consuming. Management efforts on older striplands may be more profitably directed toward retarding succession on naturally revegetated areas and establishing food producing plants.

The importance of providing food was evident in the analysis of crops of bobwhites collected on the research area (Table 2). Crops of quail collected in 1959 contained Korean lespedeza, German millet, black locust, tickclover, dwarf sumac, and wild black cherry in amounts in excess of 1% of the total volume. Korean lespedeza was the most important single food, occurring in 94% of the crops and yielding 73% of the total volume.

Though a small sample for comparative purposes, the crops of six bobwhites collected on the area in 1955 contained seeds of corn (available in a food plot), trailing wild bean (*Strophostyles helvola*), small wild bean (*S. leiosperma*), rushfoil (*Crotonopsis elliptica*), lance-leafed ragweed (*Ambrosia bidentata*), beg-

gar-ticks (*Bidens* spp.) and grasshoppers in amounts exceeding 1% of the total volume (Verts 1956). Davison (1958) classified trailing and small wild beans and rushfoil as inferior quail foods. Even though available in very limited amounts, cultivated species comprised 50% of the volume of the crops (primarily corn). Korean lespedeza was not recorded in any of the crops.

The establishment of several covey ranges could be correlated with the development of food plots in the spoilbanks, especially where Korean lespedeza had been planted. A total of 227 observations of coveys was recorded during the winters of 1957-58 and 1959-60; 70% of these occurred in or immediately adjacent to patches of Korean lespedeza. Quail began using this lespedeza as the seeds matured in late September and early October. Continued and intensive use of lespedeza plantings was recorded until other foods became available in late March and early April even when harassed by hunters during the legal season.

Broods of quail utilized food patches on the unmined areas during the summer; this use continued until the hunting season in November, indicating the importance of managing unmined areas associated with stripped lands. Following the initial exposure to hunting, however, the birds could only infrequently be located near the food patches or even on the unmined tracts. Stoddard (1931) reported that dog handlers spoke highly of small food patches as being a great help in locating coveys when they started to train their dogs in the fall. In Stoddard's study, general use of the food patches ceased soon after work with the dogs began. Utilization of the food plots on the unmined areas followed a similar pattern, but continued use of introduced foods within the spoilbanks was noted even after constant harassment by hunters.

One of two coveys utilizing a food patch in 1959-60 was completely annihilated after being located on six separate occasions during the hunting season in the same food patch; the other covey was reduced to one-half of the original number, but continued to utilize the food plot. The food plots within the spoils served as starting points for hunters with dogs and high success was recorded in locating coveys during 1959-60. Quail were not always present within the plots, but were often trailed from the plots by dogs. Though Stoddard (1931) warned against localization of coveys during the hunting season to prevent over harvest unless shooting is controlled, localization is necessary for management of quail on strip-mined lands.

A few of the coveys on the entire area may bear the brunt of the hunting pressure, but the terrain and availability of escape cover generally makes the hunting of singles unprofitable. Careful observation of flushed birds sometimes makes a second contact with a segment of a covey possible. The distribution of the coveys throughout the research area in 1959-60 was such that a number of coveys were not located by hunters during the season. The danger of over harvest is considered to be very minor.

Summary

Responses of bobwhite quail to

management practices applied on 920 acres of strip-mined land in southern Illinois have been studied since 1954. Practices employed included road construction, grading of spoils and widening of spoil valleys, manipulation of cover and introducing plant species which produce food for quail. An increase of bobwhites from 46 prior to incorporation of management to 279 in 1959-60 was recorded. An analysis of the crops of 49 quail obtained in 1959-60 indicated a dependence of the birds on plant species introduced through management.

Huntable populations of quail on naturally revegetated spoilbanks depends largely on the establishment of a suitable food supply and to a lesser extent upon altering the vegetative pattern to provide diversity. Large tracts with extremely homogeneous vegetative cover are as detrimental to quail populations as are farmlands where cover is wanting. Efforts should be directed toward retarding or disrupting the natural plant establishment by bulldozing, burning or application of herbicides. The selection of specific spoilbanks to manage would depend upon the topography and the accessibility for hunting. Less expense would be incurred if management practices were initiated as soon after mining as possible. This would result in less competition as pioneer species would not have become firmly established.

Literature Cited

Birkenholz, D. E. 1958. Reclamation of a spoil-bank area for wildlife purposes. Master of Arts Thesis, Southern Illinois University Library, 70 pp. (Unpublished).

Brewer, R. and E. D. Triner. 1956. Vegetational features of some strip-mined land in Perry County, Illinois. Trans. Ill. State Acad. Sci., 48: 73-84.

Davison, Verne E. 1958. A summary and reclassification of bobwhite foods. Journ. Wildl. Mgmt., 22(4): 437-8.

Jones, G. N. 1950. Flora of Illinois, 2nd ed. Amer. Midl. Nat. Monog. 5, University of Notre Dame Press, Notre Dame, Ind., 368 pp.

Klimstra, W. D. 1958. Progress quarterly report of the Cooperative Wildlife Research Laboratory, Oct.-Dec., Cooperative Wildlife Research Laboratory, Southern Illinois University, Carbondale, Illinois. (Typewritten).

Klimstra, W. D. 1959. Progress quarterly report of the Cooperative Wildlife Research Laboratory, Oct.-Dec., Cooperative Wildlife Research Laboratory, Southern Illinois University, Carbondale, Illinois. (Typewritten).

Klimstra, W. D. 1959. The potential of wildlife management on strip-mined areas. Illinois Wildlife, 14(2): 5-9.

Stoddard, Herbert L. 1931. The bobwhite quail—its habits, preservation, and increase. Charles Scribner's Sons, N. Y., 559 pp.

Verts, B. J. 1956. An evaluation of wildlife and recreational values of a strip-mined area. Master of Science Thesis, Southern Illinois University Library, 61 pp. (Unpublished).

Verts, B. J. 1957. The population and distribution of two species of *Peromyscus* on some Illinois strip-mined land. Journ. Mammal., 38(1): 53-59.

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ON MULTIPLY MUTANT SETS

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In this paper we will extend and develop some of the results of two earlier papers (Mullin, 1960, 1961). First we consider non-empty sets on which there is defined some non-empty index set of closed *binary* composition laws. Secondly, we show some concrete and general properties of sets that satisfy an anti-closure condition relative to all of the elements of some non-empty subset of the index set of composition laws.

In the additive and multiplicative monoids of non-negative integers the set of all odd primes is a doubly mutant set, i.e., it is a mutant with respect to both addition and multiplication.

Results

Prelemma: Consider the algebraic system determined by the additive and multiplicative monoids of non-negative integers. Then there exists, *in a constructive sense*, a maximal doubly mutant set of that system.

Proof: Put E equal to the set of all odd primes, i.e., $\{3,5,7\ldots\}$. Consider the following infinite sequence A_j of infinite sets:

$$A_0 = E,\ A_1 = \left\{ P_{i_1} P_{i_2} P_{i_3} : P_{i_j} \in E \right\},\ \ldots,$$

$$A_n = \left\{ P_{i_1} P_{i_2} \ldots P_{i_{2n+1}} : P_{i_j} \in E \right\},\ \ldots.$$

Then, clearly, $\bigcup_{i=0}^{\infty} A_i$ is a maximal doubly mutant set of the system, relative to all positive odd integers. To demonstrate that result recall that the set of all odd integers is a maximal mutant under addition and make use of the Unique Factorization Theorem of arithmetic.

Definition: Consider an algebraic system $(A, *_j)$ where $j \in J$ and J is non-empty. A set is said to be *p-tuply* mutant in $(A, *_j)$ where $0 < p \leq \text{card } J$, provided that the set is a mutant with respect to p and at most p of the composition laws.

Lemma: Let φ be a homomorphism from $(A, *_j)$ onto (B, o_k) for all $j \in J$ and $k \in K$ with, say, card $J \leq$ card K. Let M be a maximal p-tuply mutant set of $(A, *_j)$ where $o < p \leq$ card J and $j \in J$. If $\varphi(\overline{M}) \subseteq \overline{\varphi(M)}$ then there exists a cardinal number q where $p \leq q \leq$ card K such that $\varphi(M)$ is a maximal q-tuply mutant set of (B, o_k) where $k \in K$.

Proof: Use the prelemma as an existence proof for multiply mutant sets. Then apply lemma 1.7 of (Mullin, 1961) q times.

Summary

Two new and fundamental propositions, relating mutant sets to elementary number theory and general algebraic systems, are given.

Literature Cited

Mullin, A. A. 1960. *A Concept Concerning a Set with a Binary Composition Law.* Trans. Ill. St. Acad. Sci., 53 (¾): 144-145.

Mullin, A. A. 1961. *Some Remarks on a Relative Anti-closure Property.* Zeit. f. Math. Logik u. Grund. d. Math., Bd. 7 (2): 99-103.

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COMPARATIVE METHODS OF TRAPPING SMALL MAMMALS IN AN ILLINOIS WOODS

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The two basic methods for censusing small mammals are live-trapping and snap-trapping. Because of its relative convenience, the latter method is the one most commonly used. However, Bole (1939) has reported an inverse relationship between the size of the sample area snap-trapped and the population density obtained, suggesting a possibility of serious error in the method.

Stickel (1946) attempted to determine the magnitude of error involved, if any, in an experiment in bottomland forest on the Patuxent Research Refuge, Maryland, in September, 1945. She live-trapped a circular 17-acre area for 7 nights with 293 Sherman metal box traps spaced at 50 foot intervals. Following this, a circular acre in the center of the 17-acre area was snap-trapped for 3 nights with 200 traps. Live-trapping indicated a density of 6 to 7 white-footed mice (*Peromyscus leucopus noveboracensis*) per acre; snap-trapping, 23 per acre. The population density obtained by snap-trapping appeared to be significantly erroneous. Therefore, she concluded that densities obtained by snap-trapping should be used only as relative indices.

Other workers drew conclusions that were contradictory to Stickel's. Goodnight and Koestner (1942) compared live-trapping and snap-trapping on two plots of Illinois prairie and concluded that, in general, 6 to 7 days were required to determine the population density by live-trapping, with 3 days of snap-trapping giving the same density. However, their plots were only 62½ meters long by 10 meters wide, and their conclusions were based on cumulative totals of 7 species. Also, spacing of live-traps and snap-traps was alike.

Buckner (1957) compared live-trapping and snap-trapping in southeastern Manitoba. He used three trapping methods: live-traps set with a 66 foot grid spacing, snap-traps with the same spacing, and a standard line of snap-traps. He concluded that the results of all three methods were reliable, except that, perhaps due to habitat conditions, snap-trapping in early summer gave a population density only one-half that of live-trapping. No white-footed mice were taken in his study.

Wetzel (1949) made several comparisons of live-trapping and snap-trapping in undisturbed woods near Champaign, Illinois. His methods were essentially similar to those of Stickel. His results, however, were directly contradictory. He found the population densities of white-footed mice obtained by live-trapping and snap-trapping to be nearly identical.

In view of these findings, the present study was undertaken to obtain additional evidence concerning the reliability of population densities obtained by snap-trapping. Field work involving live-trapping of 13.9 acres was carried out in an upland deciduous woods in Illinois in July and August, 1960. *Peromyscus leucopus noveboracensis* was used as the experimental animal.

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Study Area

Geographic location and climate. The tract of land comprising the study area is the E½, SE¼, SE¼, Sec. 1, T.8N., R.6E., in the northeastern part of Effingham County, in south-central Illinois. The latitude is 37°10′ N; the longitude, 88°28′ W. The Shelbyville glacial moraine, the dividing line of the dark soils to the north and the light soils to the south, is 20 miles north of the area. Drainage is to the Little Wabash River and thence into the Wabash and Ohio rivers.

The climate is characterized by a wide range of temperatures. The maximum summer temperature is 100° F or more. During the summer, there are often extended periods of hot, dry weather. The minimum winter temperature may be below -10° F. The temperature may fluctuate widely during the winter, with an occasional extended cold spell. The average monthly temperature of January is 31.5° F; that of July, 77.4° F (Illinois Climatological Data, 1958). These represent the low and the high average monthly temperatures. The average annual rainfall is about 40 inches. The high average monthly rainfall (4.51 inches) occurs in June; the low (2.16 inches), in December (Illinois Climatological Data, 1958).

Geologic history, topography, and soil types. The present appearances and characteristics of the study area resulted primarily from the effects of Pleistocene glaciation. Of the four advances of the ice-sheet into Illinois during the Pleistocene, only the third, or Illinoian, reached the study area. It left drift deposits that constitute the present subsoil. The topsoil is formed of loess deposits blown in during interglacial periods. It varies in thickness, but averages only a few inches.

Drainage of the area occurs in 3 directions. To the south, drainage occurs through an east-west ditch, with two fingers extending 300 to 500 feet northward. A large percentage of the remaining area drains westward to the creek. Some drains northward through a shallow ravine extending to the creek. A small area near the center is relatively flat. The greatest difference in ele-

vation is about 30 feet, the highest elevation being a little more than 600 feet above sea level.

Management history. The study area has been the property of the present owners for 35 years. During that time, it has never been pastured and none of the boundaries have been fenced. Occasionally some of the larger trees were cut for lumber. Even then, only the logs were removed from the woods, the rest of the tree being left to rot. Dutch elm disease has caused high mortality to the American elms. High winds annually bring down many of these dead elm trees along with other branches and trees. As a result of wind action and logging operations, a great amount of rotting debris is scattered throughout the woods. A system of logging roads, most of it overgrown with herbs and small saplings, branches out from an exit located near the center of the eastern border of the woods.

Fauna. No attempt was made to define the invertebrate community. Vertebrate species observed during the trapping operations were listed. The Fowler toad (*Bufo woodhousei fowleri*) and the leopard frog (*Rana pipiens*) were the only amphibians noted. The eastern box turtle (*Terrapene carolina*) and the five-lined skink (*Eumeces fasciatus*) were the commonly observed reptiles. The avian species noted most often was the tufted titmouse (*Parus bicolor*). The cardinal (*Richmondena cardinalis*), blackcapped chickadee (*Parus atricapillus*), blue jay (*Cyanocitta cristata*), white-breasted nuthatch (*Sitta carolinensis*), whip-poor-will (*Caprimulgus vociferus*) and red-bellied woodpecker (*Centurus carolinus*) were also commonly observed.

Three species of mammals were caught in the live-traps: white-footed mouse (*Peromyscus leucopus noveboracensis*), short-tailed shrew (*Blarina brevicauda*) and eastern chipmunk (*Tamias striatus*). Individuals of three other species, the eastern cottontail (*Sylvilagus floridanus*), eastern gray squirrel (*Sciurus carolinensis*) and eastern fox squirrel (*Sciurus niger*) were observed. Four species were known by sign only. These were the red fox (*Vulpes fulva*), striped skunk (*Mephitis mephitis*), opossum (*Didelphis marsupialis*) and raccoon (*Procyon lotor*). The southern flying squirrel (*Glaucomys volans*) has occasionally been observed during logging operations.

Flora. A dense stand of shrubs and trees was present over most of the study area. White oak (*Quercus alba*), black oak (*Quercus velutina*), shagbark hickory (*Carya ovata*), bitternut hickory (*Carya cordiformis*) and green ash (*Fraxinus pennsylvanicus*) were the dominant tree species. Other species were present, but insignificant as regards crown cover. Poison-ivy (*Rhus radicans*) was the most prevalent shrub, occurring in dense patches, as scattered erect plants, and as climbing vines. Other common shrub species were buckbrush (*Symphoricarpos orbiculatus*), Virginia creeper (*Parthenocissus quinquefolia*) and riverbank grape (*Vitis riparia*). White snakeroot (*Eupatorium rugosum*) was the most prevalent herb, being present over most of the area. Other common herbs were the Virginia knotweed (*Poly-*

gonum virginianum), false Solomon's-seal (*Smilacina racemosa*), mayapple (*Podophyllum peltatum*) and common wood-sorrel (*Oxalis cymosa*).

Materials and Methods

Traps and baits. Two types of live-traps were used in this study. One was constructed mostly of wood, with a hardware cloth top and galvanized metal door. The trigger mechanism was of the type described by Fitch (1950). The other was constructed of hardware cloth. Its trigger mechanism was a modified and improved version of the former, a swinging hardware cloth partition and brass wire fulcrum replacing the heavy wire mechanism. No more than 6 of the latter type were used at any one time. Museum Special snap-traps were used.

Preliminary trapping to find a convenient and effective bait was begun on July 1. After 4 days of experimental trapping, shelled corn soaked in peanut oil was determined to be a suitable bait for the live-traps. To have a somewhat comparable bait for the snap-traps, cornmeal, mixed with peanut oil to a crumbly consistency, was used.

Trap layout. All of the live-trap locations employed during this study are shown in Figure 2A. For convenience, all of the locations are shown as spaced at 50 foot intervals. Such preciseness was not the case, however, for no attempt was made to space the traps at exact 50 foot intervals. The trap locations were marked by means of strips of white cloth hung from convenient branches. When setting the traps, they were not all set just below the markers, but at favorable locations within 10 feet. There were 242 trap locations, but no more than 177 were utilized at any one time. Total effective coverage was 13.9 acres, each trap location being assigned an area of 2500 square feet.

The location of the circular acre in which snap-trapping was carried out is also shown in Figure 2A.

Field techniques. Marking was accomplished by clipping the distal 2 joints of a toe, or combination of toes, on the front feet. Age was determined by use of the juvenile molt pattern described by Gottschang (1956). Three age classes were recognized: juveniles — those not yet starting the juvenile molt; subadults — those in the process of the juvenile molt; adults — those having completed the juvenile molt. Two breeding conditions were recognized for males: testes descended and testes not descended. Three breeding conditions were recognized for females: not visibly pregnant, pregnant and nursing.

Trapping methods. The essence of the trapping procedure was to live-trap a large area until the apparent home range of supposedly all the individuals was known, and then to snap-trap a central acre for a 3-day period. In live-trapping, the traps were set in late afternoon or early evening and checked the following morning, at which time they were snapped. The decision to leave the traps unset during the midday was influenced by two factors. Ants quickly carried off unprotected bait. With the traps closed, it was not possible for the ants to remove the

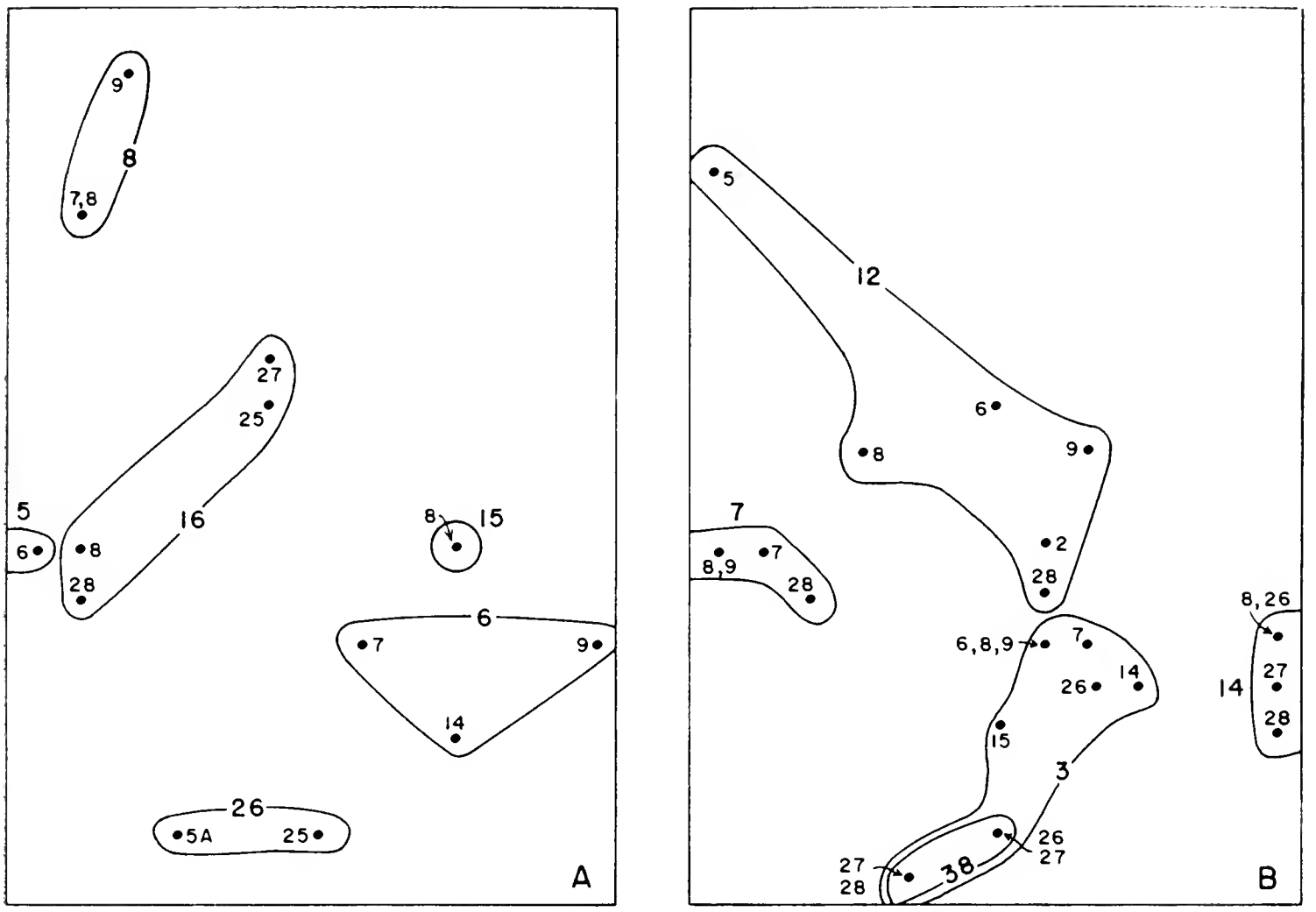

Fig. 1.—Live-trapping and snap-trapping results for *Peromyscus leucopus*. A and B, location and date of each live-capture for all individuals. C, composite of apparent ranges (note amount of overlap). D, snap-trapping results, showing date and location of last previous live-capture. Point at which individual was taken in snap trap is shown by an X. No. 36 not previously taken in a live-trap. Small numbers indicate date of capture in July except where "A" indicates date of capture in August. Where ranges of Numbers 3 and 38 overlap, lower dates are for No. 3.

kernels of corn. Also, the midday heat would very likely have caused the death of any animal captured shortly after the traps had been checked in the morning.

After a suitable bait was found, live-trapping in rows 6 through 19 (see Fig. 2A) was continued through July 9. Trapping records for mice captured more than once indicated that all but one seemed to have home ranges near the periphery of the trapping area. All but 2 were near the southern edge. A large rectangular barren area of nearly 5 acres seemed to exist. Eighty-four traps were set within this area on the afternoon of July 11. There were no captures the following morning. It was felt that snap-trapping a central acre, most of which was apparently unoccupied, would be of little or no value. Consequently, the traps in rows 18 and 19 were taken up and 19 of them placed in the form of an "E" within the area of rows 1 through 5. It was felt that this would probably reveal the presence of any new individuals within that area. However, in 3 nights of trapping, July 13, 14, and 15, only 3 captures were made, all of the mice being individuals previously marked in the adjacent area. After a one-week delay, the traps in rows 14, 15, 16, 17, 18, and 19 were used to fill in rows 1 through 5, which bordered the area where most of the mice were caught. This arrangement of traps was thought to

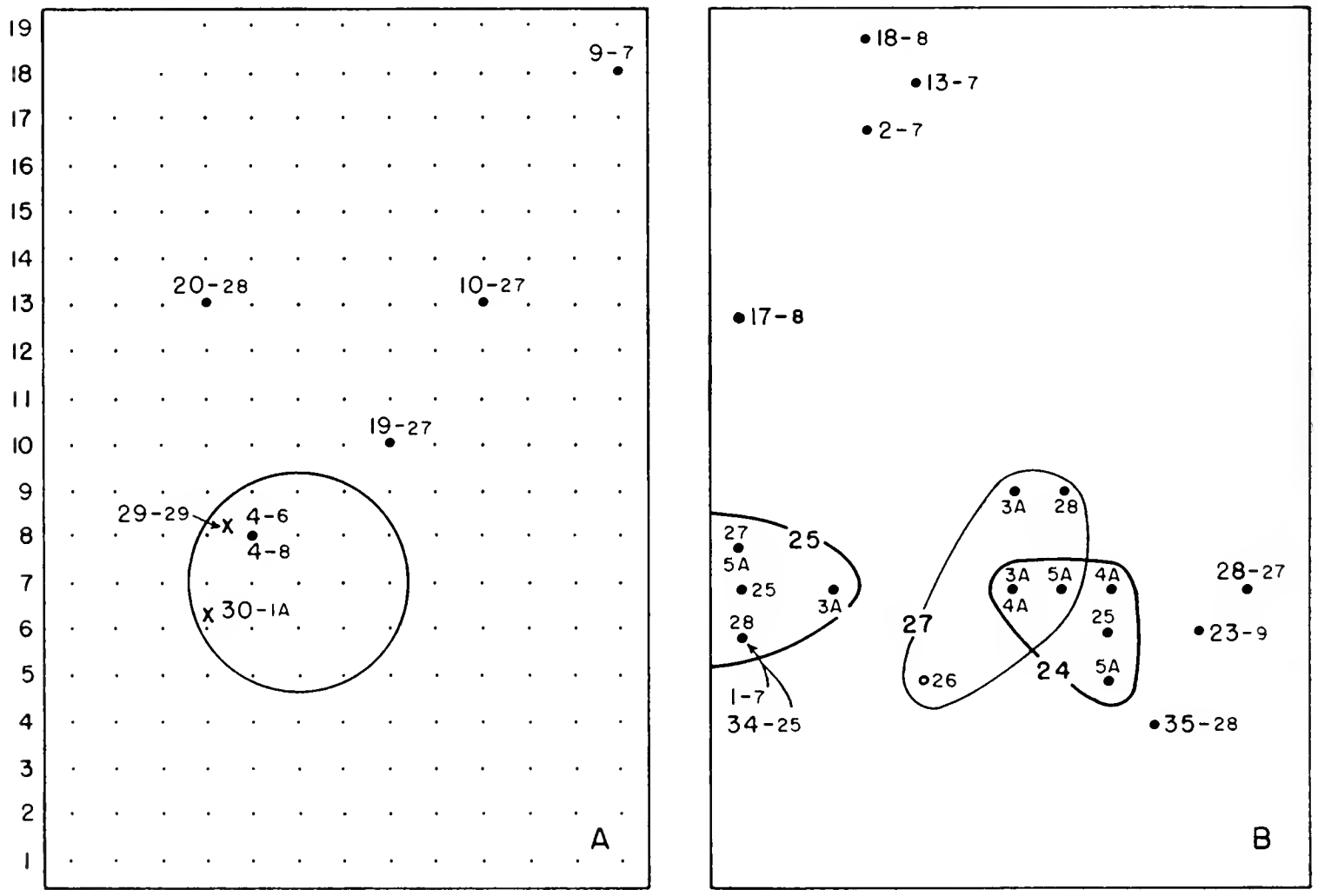

Fig. 2.—Trapping results for *Blarina brevicauda* and *Tamias striatus*. A indicates date in August. Number preceding the hyphen is the number of the individual; that following, the date of capture. A, date and location of each capture of a short-tailed shrew. Capture in a snap-trap indicated by an X. Dots represent live-trap locations used during this experiment. Circle represents 1-acre snap-trapping area. B, date and location of each capture of a chipmunk.

permit the obtainment of more adequate data on home range. Live-trapping in rows 1 through 13 was then carried on for 4 nights, beginning July 25. An exception occurred on July 26 when, due to a thunderstorm, only the traps in rows 2. 3, 4, 5, 6, and 7 had been set the previous afternoon. After this period, the location and apparent home range of all or a majority of the individuals was known.

Snap-trapping was begun on July 29. A circular acre was marked off, using the eighth trap from the east end of row 7 as the center (Fig. 2A). This was one trap position removed from the center of the area covered by the live-traps in rows 1 through 13. The reason for this dissymmetry was practical, rather than scientific. The author wished to avoid an extensive patch of poison-ivy. A total of 160 traps was set within this acre. In each quarter of the acre, 40 traps were set at random. Snap-trapping was carried on for 5 nights. The first three nights were used to determine population density, the last 2 only to see if the rate of ingress changed. As a further check on movements, live-trapping was continued in rows 1 through 13 on August 3, 4, and 5, at which time thievery by a squirrel hunter forced a halt to trapping operations.

Results

Trapping success. The results of live-trapping are summarized in Table 1. Individuals of 3 species were captured. *P. leucopus* will be treated extensively. Data for the other 2 species will be treated later in summary form. Live-trapping was conducted 15 nights before and 3 nights after snap-trapping, for a total of 18 nights. Of the former, the 8 nights included in the periods of July 6 through 9 and 25 through 28 are of primary importance. During these 8 nights, which represented only 71.6 per cent of the total trap nights (1679), 91.4 per cent of the total captures (58) occurred. July 1, 2, and 5, represented 21 per cent of the trap nights, but accounted for only 3.4 per cent of the captures. This period occurred before a suitable bait was found. The period of July 12 through 15 represented 7.5 per cent of the trap nights, and accounted for 5.2 per cent of the captures. This was a period of exploratory trapping.

Eleven white-footed mice were taken a total of 38 times, or an average of nearly 3.5 captures per individual. By July 9, the fourth day of effective trapping in rows 6 through 19, all of the mice taken were recaptures. In the effective trapping of rows 1 through 13, no new individuals were found after the second day.

A summary of snap-trapping results is given in Table 2. Of the 6 marked mice captured, 4 were taken the first night, one the third night, and one the fourth night. An unmarked individual was taken the third night. No individuals were caught the second and fifth nights.

Population composition. Of a total of 12 individuals taken during the present study, 7 were males and 5 were females. The age classes were somewhat difficult to categorize, since some individuals progressed to a succeeding age class during the trapping period. For convenience, the age class of an animal at its initial capture has been given in Table 3.

TABLE 1.—Live-trapping results.

Date	No. of traps set	*P. leucopus*			*B. brevicauda*			*T. striatus*			Total
		New individuals	Recaptures	Total	New individuals	Recaptures	Total	New individuals	Recaptures	Total	
	Pre-snap-trapping										
July 1...	177	0	0	0	0	0	0	0	0	0	0
2...	104	1	0	1	0	0	0	0	0	0	1
5...	73	0	1	1	0	0	0	0	0	0	1
6...	78	2	1	3	1	0	1	0	0	0	4
7...	177	3	1	4	1	0	1	3	0	3	8
8...	177	3	4	7	0	1	1	2	0	2	10
9...	177	0	5	5	0	0	0	1	0	1	6
12...	68	0	0	0	0	0	0	0	0	0	0
13...	19	0	0	0	0	0	0	0	0	0	0
14...	19	0	2	2	0	0	0	0	0	0	2
15...	19	0	1	1	0	0	0	0	0	0	1
25...	169	1	1	2	0	0	0	2	0	2	4
26...	84	1	2	3	0	0	0	1	0	1	4
27...	169	0	4	4	2	0	2	1	1	2	8
28...	169	0	5	5	1	0	1	1	2	3	9
Total..	1679	11	27	38	5	1	6	11	3	14	58
	Post-snap-trapping										
Aug. 3....	169	0	0	0	0	0	0	0	3	3	3
4....	169	0	0	0	0	0	0	0	2	2	2
5....	163	0	1	1	0	0	0	0	3	3	4
Total..	501	0	1	1	0	0	0	0	8	8	9

TABLE 2.—Snap-trapping results.

Date	Total individuals	*P. leucopus*			*B. brevicauda*		
		Marked	Unmarked	Total	Marked	Unmarked	Total
July 29.....	5	4	0	4	0	1	1
30.....	0	0	0	0	0	0	0
31.....	2	1	1	2	0	0	0
Aug. 1.....	2	1	0	1	0	1	1
2.....	0	0	0	0	0	0	0

Of 7 males, 3 were juveniles, 3 were sub-adults and one an adult. None of the males had descended testes until the last week of July, when all males captured had descended testes. One juvenile, 2 subadult, and 2 adult females were taken. None was pregnant or nursing.

Distribution. The location and date of capture for each mouse taken are shown in Figures 1A and 1B. From these data, an approximation of the home range of each individual has been drawn. All of the home ranges are shown in Figure 1C. A large amount of apparently unoccupied space is evident. Clumping is so pronounced that every individual captured more than once shows some degree of overlap of home range. The home ranges vary considerably in size and shape. The numbers involved are too few and the variations too extreme to make data on size of home range meaningful.

The location of the one-acre plot that was snap-trapped is shown in Figure 1D. Each of the 6 mice taken in a snap-trap is noted. The date of capture and the approximate location of the trap in which it was taken is given, along with the location and date of the last capture in a live-trap.

Movement. The maximum distance between recaptures is given for each individual in Table 4. The greatest distance was 570 feet (12). The least was 100 feet (14). The average for the 9 individuals captured more than once was 234 feet. For 6 males it was 229 feet; for 3 females, 243 feet. One mouse (12) moved 525 feet during a 3 night period, and the next night moved 390 feet back toward the original point of capture.

The distance traveled from the last previous capture to the point at which the animal was taken in a snap-trap is given in Table 5. Only 2 animals were taken on consecutive dates. One (3) traveled the greater distance, while the other (12) traveled the shortest distance. The remaining animals traveled intermediate distances over periods varying from 3 to 21 days.

Population densities. From the 13.9 acres live-trapped, only 11 white-footed mice were taken. This gives a population density of 0.8 mice per acre. By employing a buffer strip, one-half of the average maximum distance between capture locations (117′) added to the periphery of the trapping area, the population density is lowered to 0.5 mice per acre.

A 3-night period of saturation trapping with snap-traps is generally thought to take all of the resident animals in a one-acre trapping area. The first 3 nights of snap-trapping in the present study yielded 6 animals, giving a population density of 6 mice per acre. Adding the same width of buffer strip as before lowers the population density to 1.5 mice per acre.

Other Mammals. Trapping data for the short-tailed shrew (*Blarina brevicauda*) are summarized in Tables 1 and 2. Five individuals were taken a total of 6 times in the live-traps, the single recapture occurring in the same trap as the initial capture and only 2 nights later. Three of the shrews died in the live-

TABLE 3.—Population composition (*P. leucopus* and *T. striatus*)

Sex	Age group	Total	
		P. leucopus	*T. striatus*
Male	Juvenile	3	..
	Subadult	3	0
	Adult	1	4
Female	Juvenile	1	..
	Subadult	2	4
	Adult	2	3

TABLE 4.—Maximum distance between recaptures of *P. leucopus*

# of individual	Sex	Age*	# of times captured	Max. distance between recaptures
3	male	J to SA	9	320′
5	female	A	1	....
6	female	A	3	260′
7	male	SA to A	4	115′
8	male	J	3	160′
12	male	J to A	6	570′
14	male	SA to A	4	100′
15	female	J	1	....
16	female	SA	4	320′
26	female	SA	2	150′
38	male	A	2	110′

*J = juvenile; SA = subadult; A = adult; "to" indicates change in age class over trapping period.

traps. Two unmarked shrews were taken in the snap-traps, one the first night and the other the fourth night.

The point of capture is given in Figure 2A for all of the animals taken. Live-trapping yielded a population density of less than 0.4 individuals per acre; snap-trapping, one per acre. Five of the 7 shrews captured apparently were females. Based on size, all of them were thought to be adults. One had been nursing young.

Data on live-trapping of the eastern chipmunk (*Tamias striatus*) are summarized in Table 1. Eleven individuals were taken alive, and another was accidentally captured and later found dead in the trap. The former were captured a total of 22 times with 3 animals accounting for all of the recaptures. None of the 3 was recaptured until the seventh day of effective trapping, at which time all but one individual had been taken at least once.

The sex and age composition of the chipmunk population is shown

TABLE 5.—Distance from last previous live-capture to point at which taken in a snap trap. (*P. leucopus*)

# of individual	Distance traveled	# of days
3.....	300′	1
6.....	160′	15
7.....	120′	3
12.....	50′	1
15.....	150′	21
38.....	200′	4

in Table 3. Age was subjectively based on size. Differential growth rates of males and females might have caused unreliable age class data, since no males were classified as subadults. One male appeared to have undescended testes, only a shriveled scrotal sac being present.

Distribution of the chipmunks is shown in Figure 2B. Approximate home ranges have been drawn for the 3 animals that were recaptured. The maximum distance between capture locations was 250 feet for an adult male (27), 140 feet for another adult male (24), and 110 feet for a subadult female (25). The average was 167 feet. The population density was less than 0.9 chipmunks per acre.

DISCUSSION

Trapping success. It was felt that all or nearly all of the white-footed mice within the trapping area were caught at least once during the live-trapping operation. This conclusion is supported by the fact that only one unmarked mouse was caught in the snap-traps. The 2 white-footed mice (3 and 12) caught most frequently also had the largest home ranges, indicating the presence of little or no trap proneness. Neither was caught more than 2 nights consecutively in the same trap.

There is evidence that the recent capture of one white-footed mouse in a live-trap predisposes that trap in some way for the capture of another individual. Three different individuals were caught in one trap within 3 consecutive nights, while in 4 other traps different individuals were caught during 2 consecutive nights. In still another trap, 2 different individuals were captured within 3 nights. These instances accounted for nearly one-third of the total captures. Thus, in many cases, the overlap of home ranges would seem to be primarily the result of an artifact. Even in nature, however, this same sort of overlap very likely occurs due to some stimulus, such as urinating posts. It may be assumed, therefore, that the data obtained from the live-trapping were reasonably reliable.

Distribution and movement. Home ranges of white-footed mice, as shown in Figure 1C, were drawn by using a 50 foot strip between successive captures. The sharp angles thus formed were then subjectively rounded off. For the purposes of this study, only an approximation of the position of the home range was needed. The variations in size and shape of home ranges was perhaps a reflection of the low population density.

The distribution pattern of the 11 mice taken was unexplainable. Large barren areas existed. Where animals were present, much overlap of home range occurred. The topography and the amount of debris

present were thought to be determining factors. The mice seemed to be in close proximity to the drainage ways and in areas containing relatively larger amounts of debris. Yet a similar situation existed in the northeastern part of the trapping area, with no mice being found. Therefore, some other factor, or a combination of factors, may have caused the clumped distribution.

The average maximum distance between recapture locations was 229 feet for 6 males and 243 feet for 3 females. The corresponding distances found by Stickel (1946) were 146 feet and 93 feet. Nicholson (1941) found that most of the mice he studied moved less than 200 feet. The animals in the present study traveled considerably greater distances, especially the females. The number of animals is so small that this variation might be due to chance alone. However, Blair (1940), in a study of the meadow vole in southern Michigan, found greater movements in areas of lower population densities.

Population densities. A total of 11 animals were taken in the live-traps. Five of 7 animals captured 3 or more times had a home range extending to the periphery of the trapping area. Therefore, some individuals may have ranged a considerable amount outside of the 13.9 acre trapping area. Some workers (Dice, 1938; Stickel, 1946; Wetzel, 1949) have used a buffer strip in their calculations in order to lessen the amount of error involved. Stickel (1946) used a buffer strip based on the average maximum distance between capture locations. In this study, the average maximum distance between capture locations was 234 feet. The addition of one-half of this amount to the periphery of the trapping area as a buffer strip gives a corrected trapping area of 24.0 acres. By this method of calculation, the population density is lowered from 0.8 to 0.5 mice per acre.

Saturation trapping of a circular acre for a period of 3 nights is a method of determining population density by the use of snap-traps. Within the 3 night period of snap-trapping in the present study, 6 mice were taken. Employing the same type of buffer strip as before, the population density obtained by snap-trapping is lowered from 6.0 to 1.5 animals per acre.

A comparison of the corrected densities shows the population density obtained by snap-trapping to be 300 per cent larger than that obtained by live-trapping. Wetzel (1949) found the density obtained by snap-trapping to be nearly identical to that found by live-trapping. The results of the present study, however, concur with and corroborate the findings of Stickel (1946). She found adjusted densities of 6 to 7 per acre by live-trapping and 23 per acre by snap-trapping, a discrepancy only slightly larger than that found by the author. The author agrees with her proposal that snap-trapping be used only as a relative index of population densities.

The low population density found in this study is worthy of special note. Wetzel (1949) found a density of 4 mice per acre in a central Illinois woods in August. Burt (1940) has given monthly population densities for the white-footed

mouse in southern Michigan. He found the lowest density in May, with another low point of the cycle occurring in July or August. Although the latter period corresponds to the time of the present study, his population density of slightly more than 5 animals per acre is much higher than that reported here. The reason for this unusually low summer population is not known.

Other mammals. Efficiency of the live-traps in taking the short-tailed shrew (*B. brevicauda*) was low. Five individuals were captured. One of these was taken in the snap-trapping area. Two unmarked individuals were taken in the snap-traps, giving a total of 3 animals within the circular acre. More than 4 shrews were surely present over the remaining 12.9 acres. Moreover, only a single shrew was recaptured.

Distribution of the shrew seemed to be scattered (Fig. 2A), individuals being found in the area left unoccupied by the white-footed mouse. No records of movement were obtained. Live-trapping yielded a population density of less than 0.4 animals per acre; snap-trapping, one per acre. The similarity might make both methods seem reliable. However, the presence of 3 shrews within the circular acre and only 4 outside of it is good evidence that at least one of the trapping methods was in error.

Efficiency of the live-traps in taking chipmunks (*T. striatus*) was similar to their efficiency in taking white-footed mice. No unmarked chipmunks were taken after 8 days of effective trapping. Three chipmunks (24, 25, and 27) seemed to be trap prone, being the only 3 recaptured of a total of 11 taken alive. One (24) was captured 4 times, the other 2 each 5 times. None showed any great movement, the average maximum distance between recaptures being 167 feet. The greatest distance traveled was 250 feet by an adult male.

A comparison of figures 1C and 2B indicates that the distribution of the chipmunk closely paralleled that of the white-footed mouse. This would suggest that surface debris might be the factor influencing the clumped distribution of both, since the shrew, primarily a sub-surface dweller, occurred where both mouse and chipmunk did not.

Twelve chipmunks, including one found dead in a trap, were taken on the study area. Only 3 individuals were recaptured, and they seemed to be trap prone. Hence, data on home ranges were meager and probably unreliable, making the calculation of a buffer strip impractical. Thus, all that can be said is that the population density was less than 0.9 chipmunks per acre.

Summary

Live-trapping of small mammals was conducted over a total of 13.9 acres of upland woods in south-central Illinois in July and August, 1960. Snap-trapping of a circular, centrally located acre was carried on for 5 nights with 160 Museum Special traps. White-footed mice (*Peromyscus leucopus noveboracensis*), short-tailed shrews (*Blarina brevicauda*), and eastern chipmunks (*Tamias striatus*) were captured in live-traps. Individuals of the former 2 species were also taken in snap-traps.

Summarization of the results may be categorized by species.

P. leucopus.—Eleven individuals were captured a total of 38 times in the live-traps. Approximate home ranges were drawn, and great variations in size and shape were noted. The average maximum distance between locations of capture was 229 feet for 6 males and 243 feet for 3 females. The population density determined by live-trapping with a 50 foot grid spacing was 0.8 animals per acre; the population density obtained by saturation snap-trapping for 3 nights, 6 animals per acre. The adjusted population densities were 0.5 for live-trapping and 1.5 for snap-trapping. A serious error in the results obtained from the snap-trapping method is indicated.

B. brevicauda.—Five individuals were taken in the live-traps and 2 in the snap-traps. No data were obtained on home ranges or movements. The population densities obtained were less than 0.4 animals per acre by live-trapping and one animal per acre by snap-trapping. The density figures are felt to be in error, especially that of live-trapping.

T. striatus.—Twelve individuals were taken, giving a population density of less than 0.9 individuals per acre. Only 3 animals were recaptured. Of these, one was taken 4 times; the other 2, 5 times. The greatest distance traveled was 250 feet by an adult male.

Bibliography

Blair, W. F. 1940. Home ranges and populations of the meadow vole in southern Michigan. Jour. Wildl. Mgt., 4(2): 149-161.

Bole, B. P., Jr. 1939. The quadrat method of studying small mammal populations. Cleve. Mus. Nat. Hist., Pub., 5(4): 15-77.

Buckner, C. H. 1957. Population studies on small mammals of southeastern Manitoba. Jour. Mamm., 38(1): 87-97.

Burt, W. H. 1940. Territorial behavior and populations of some small mammals in southern Michigan. Mus. Zool., Univ. Mich., Misc. Pub. 45.

Dice, L. R. 1938. Some census methods for small mammals. Jour. Wildl. Mgt., 2(3): 119-130.

Fitch, H. S. 1950. A new style live-trap for small mammals. Jour. Mamm., 31(3): 364-365.

Goodnight, C. J., and E. J. Koestner. 1942. Comparison of trapping methods in an Illinois prairie. Jour. Mamm., 23(4): 435-438.

Gottschang, J. L. 1956. Juvenile molt in *Peromyscus leucopus noveboracensis*. Jour. Mamm., 37(4): 516-520.

Illinois Climatological Data, Annual Summary. 1958. Volume LXIII, No. 13.

Nicholson, A. 1941. The homes and social habits of the wood-mouse (*Peromyscus leucopus noveboracensis*) in southern Michigan. Am. Midl. Nat., 25(1): 196-223.

Stickel, L. F. 1946. Experimental analysis of methods for measuring small mammal populations. Jour. Wildl. Mgt., 10(2): 150-159.

Wetzel, R. M. 1949. Analysis of small mammal population in the deciduous forest biome. Unpublished Ph.D. thesis, Univ. Ill.

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ABSENCE OF RABIES IN SOME BATS AND SHREWS FROM SOUTHERN ILLINOIS

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During July, 1958, a project was initiated in southern Illinois to determine the relationship of distribution, abundance, and ecology of wildlife vectors to the incidence of rabies (National Institutes of Health Project E-1349). Two of several related studies involved the collection and testing of bats and shrews for rabies.

The fact that bats sometimes carry rabies is becoming well known; each year several bats are received for rabies determination in the laboratories of the Illinois Department of Health. The history of chiropteran rabies in the United States and elsewhere has been well summarized by Martin (1959). In October, 1959, Illinois became the twenty-third state to report bat rabies (U. S. Dept. of Hlth., Ed., and Welfare, 1959), and Kansas recently became the thirty-first state to report rabies in bats (U. S. Dept. of Hlth., Ed., and Welfare, 1961).

Insectivores as possible natural hosts for rabies are discussed by Verts and Barr (1960), but no reference concerning rabid shrews has been found. Two hundred and sixty-six shrews (Verts and Barr, 1960) and 559 bats (Verts and Barr, 1961) from northwestern Illinois have been tested for rabies, all with negative results.

In the present study, 93 bats, representing seven species, were collected from abandoned silica mines and natural caves in three counties (Union, Alexander and Pulaski) in southern Illinois between December, 1958, and March, 1959 (Table 1). All bats were captured within a radius of less than 16 miles from a site where rabid skunks were found in June and September, 1958. Twenty-five shrews and one mole were caught from August, 1958 to April, 1959 (Table 2); nine of the shrews were trapped within ¼ mile and the remainder less than 20 miles from recent sites of rabies.

Brain and salivary gland tissues from all insectivores and 35 of the bats were removed in the laboratory and stored in a deep-freeze cabinet at minus 20° C in separate tubes containing a solution of equal volumes of glycerine and twice-normal physiological saline until all tests had been completed. Laboratory technique for testing these tissues was the same as described by Verts and Barr (1960).

The remaining 58 bats were tested by Mr. Nathan Nagle, Director, Illinois Department of Health Laboratory, Carbondale. Some of the tissues were preserved in the manner previously described, but most brains

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TABLE 1.—Species of bats and numbers of tissues tested for rabies from southern Illinois.

Species	Number of brains examined	Number of salivary glands examined
Pipistrellus subflavus	38	38
Myotis keenii	17	17
Myotis lucifugus	6	6
Myotis sodalis	1	1
Eptesicus fuscus	15	15
Plecotus rafinesquii	8	8
Lasionycteris noctivagans	8	8
Totals	93	93

TABLE 2.—Species of insectivores and numbers of tissues tested for rabies from southern Illinois.

Species	Number of brains examined	Number of salivary glands examined
Blarina brevicauda	24	24
Sorex longirostris	1	1
Scalopus aquaticus	1	1
Totals	26	26

and salivary glands were placed in sterile glycerine when removed from the animal. They were allowed to stand for 24 hours at room temperature before being used in mouse inoculation tests. Sections of brain and salivary gland tissues from each bat were ground with pestle and mortar into an emulsion, mixed with nine parts of 0.9 per cent saline and allowed to stand for 5 minutes at room temperature. Quantities of 0.03 ml of the supernatant fluid from each suspension were injected intracerebrally into three 4- to 6-week old mice using a 0.25 ml tuberculin syringe and a 27 gauge needle; this is essentially the mouse inoculation test described by Koprowski (1954). Mice dying within 4 days after inoculation were considered to have succumbed for rea-

sons other than rabies infection. The inoculated mice were observed for 28 days.

Results of tests of all tissues were negative for rabies. The possibility of finding rabid shrews and bats by random collections is apparently remote, but those exhibiting unusual behavior will continue to be ex-- amined.

Literature Cited

Koprowski, H. 1954. Laboratory techniques in rabies. Wld. Hlth. Org. Mono. Ser., No. 23, pp. 56-68.

Martin, R. L. 1959. A history of chiropteran rabies with special reference to occurrence and importance in the United States. Wildl. Dis., 3, 75 pp.

U. S. Department of Health, Education, and Welfare. 1959. Veterinary Public Health Newsletter; prepared by Veterinary Public Health Section of Epidemiology Branch, Communicable Disease Center, Atlanta, Ga. November. 16 pp. Mimeo.

U. S. Department of Health, Education, and Welfare. 1961. Veterinary Public Health Section of Epidemiology Branch, Communicable Disease Center, Atlanta, Ga. January. 14 pp. Mimeo.

Verts, B. J. and Thomas R. B. Barr. 1960. Apparent absence of rabies in Illinois shrews. J. Wildl. Mgmt., 24(4): 438.

Verts, B. J. and Thomas R. B. Barr. 1961. An effort to identify rabies in bats from northwestern Illinois. Cornell Vet. (in press).

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ROOT GROWTH OF TRANSPLANTED LOBLOLLY PINE (*PINUS TAEDA* L.) SEEDLINGS IN RELATION TO CHEMICAL ROOT RESERVES

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The ability of a seedling to produce new roots after being transplanted from the nursery affects the possibility of its survival. The general practice in nurseries growing loblolly pine seedlings is to run a lifting blade eight inches below the soil surface to remove the seedlings with the least amount of damage. Most of the fine rootlets and all roots more than eight inches below the soil surface are lost during this operation. This reduction in the amount of moisture absorbing surface as compared to the transpiring surface is critical and undoubtedly often determines if a seedling will survive.

Stone (1955) demonstrated that new root growth is necessary for survival of ponderosa pine and Douglas-fir when transplanted, but he did not determine which factors were associated with the production of new roots. Reed (1939) observed that root growth of field-planted pine seedlings in North Carolina is hindered by low soil moisture before the wilting point is reached. This means that a seedling transplanted into the field must produce new roots before soil moisture becomes low in early summer if the plant is to survive.

Many investigators have reported the presence of sugars, starches and other carbohydrate fractions in plants and plant parts, but the literature is nearly devoid of references to the role that carbohydrates play in the survival of transplanted seedlings. A high carbohydrate content in the roots of a seedling at the time of transplanting could indicate a high capacity to supply energy necessary for the production of new roots.

Wakeley (1954) reported that shading southern pine seedlings in nursery beds, reduced the survival of outplanted longleaf pine seedlings 26 per cent and slash pine seedlings 79 per cent. He attributed the high mortality to the failure of the shaded seedlings to develop new roots promptly after transplanting.

Wassink and Richardson (1951) reported that root growth of first year seedlings of sycamore maple was directly related to light intensity, while root growth of red oak seedlings of the same age appeared to depend on stored food rather than on products of current photosynthesis. In another study, Richardson (1953) reported that when photosynthesis was curtailed, root growth of silver maple proceeded at the expense of food stored in the roots. He also found that the leaves supply a stimulus essential to root formation and growth.

Reines (1957) in his comprehensive review of rooting southern pine

states that many studies have been reported where the effects of carbohydrates on rooting of plant cuttings is mentioned.

Although little work has been done on root growth of transplanted pine seedlings, results from several studies indicate that root growth of seedlings might be dependent on the carbohydrates in the plant. In an early study using root growth chambers, the author found that a weak statistical relationship existed between the carbohydrates in the roots and root growth of transplanted loblolly pine seedlings; but, because of the wide variation in root growth, it was difficult to reach a positive conclusion regarding root growth and reserve root carbohydrates.

Carbohydrates are known to be translocated from the leaves through the stem phloem and into the roots. If this path of translocation could be blocked at the time of transplanting, carbohydrates would be prevented from entering the roots and a test could be made to determine the correlation between the carbohydrates in the roots at this time and during subsequent root growth. A scheme was devised that fulfills these requirements and enabled the investigator to test the results of the early study more thoroughly.

Methods

Twenty 1-year-old loblolly pine seedlings that were used in the exploratory phase of the experiment were girdled in the late spring of 1959. These seedlings and 20 control seedlings (not girdled) were planted in cans. All seedlings were removed after 30 days and the roots visually examined to determine whether or not root growth had begun.

Year-old seedlings used in the main part of the experiment were removed from the nursery bed each month from October, 1959 through April, 1960. Forty seedlings were girdled each month and then planted in root growth chambers. To serve as a control, each month 20 ungirdled seedlings were planted in gallon containers. All seedlings were observed over a 30-day period for root growth.

Results

During the exploratory phase of the experiment in the spring of 1959 a light pressure with the thumbnail was all that was required to remove the bark around the seedling stem. Both seedlings that were girdled and ungirdled developed new branch roots in addition to elongation of old roots after they were transplanted. Root growth was approximately four times greater on ungirdled seedlings than on girdled ones.

Seedlings removed from the nursery bed in October, 1959 and during the next 6 months, appeared to be in a dormant state. The bark adhered to the stem very tightly in all 7 groups of seedlings. To girdle a seedling it was necessary to double ring the stem with a razor blade and then scrape away the bark.

None of the seedlings girdled during the period from October, 1959 through April, 1960 showed any visible root growth after they were transplanted. In contrast, seedlings that were not girdled during this period developed new roots in addition to elongation of old roots.

Only a few of the girdled or ungirdled seedlings in the experiment died within 30 days after they were transplanted. A large percentage of seedlings girdled and transplanted in March and April of 1960 started height growth and the seedlings appeared to be healthy except for the girdle on the stem.

Discussion

The primary difference between seedlings transplanted in the late spring 1959 and those transplanted during the period from October, 1959 to April, 1960 must have been in their growing status. It is well known that easy mechanical removal of bark from trees occurs only when the cambium is physiologically active (Kramer and Kozlowski, 1960, p. 8). The fact that bark could be removed easily from the stems of seedlings girdled in the spring of 1959 but was difficult to remove during the other periods indicates that the former were physiologically active, whereas the other girdled groups of seedlings were in a dormant state.

Root growth of seedlings girdled in the spring of 1959, that were thought to be physiologically active at time of girdling, is not a significant event in itself. However, when compared with dormant girdled seedlings that produced no new roots after being transplanted, the results suggest that before a seedling can produce new roots, the roots must receive some stimulus from the leaves or buds.

The supposition that a root growth stimulus is translocated from the top of the seedlings to the roots is further substantiated by the two groups of seedlings tested in the spring of 1959. As previously stated, all seedlings in the spring of 1959 appeared to be in an active state of growth; seedlings from both groups developed new roots. If root growth did not depend upon a stimulus from the needles or buds, the total amount of root growth should be the same in both groups of seedlings. The fact that this did not result suggests that it is necessary to replenish some substance in the roots before root growth can proceed at the same rate as in ungirdled seedlings. This substance cannot be stored in roots, otherwise dormant girdled seedlings would produce new roots. This material probably is not one of the major carbohydrates (reducing sugars, sucrose, or starches) found in pine seedling roots, as loblolly pine roots contain relative large quantities of such carbohydrates during periods in which transplantings are made.

As previously stated, none of the girdled seedlings during the 7 month period produced either new roots or elongation of old roots. For this reason the carbohydrate content in the seedlings roots was not determined, as no correlation could possibly be established between root growth and food reserves of the roots.

Summary

No correlation was shown between root growth of transplanted seedlings and food reserves of roots. However, certain results indicate that before root growth can begin, the roots must receive a stimulus from the leaves or buds.

Acknowledgments

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Literature Cited

Kramer, P. J. and T. T. Kozlowski. 1960. Physiology of trees. McGraw-Hill, New York, 642 pp.

Reed, John F. 1939. Root and shoot growth of shortleaf and loblolly pines in relation to certain environmental conditions. Duke Univ. Sch. For Bull., 4, 52 pp.

Reines, M. 1957. Rooting of southern pines. Proc. Fourth Sou. Conf. For. Tree Improv., Athens Ga., pp. 116-121.

Richardson, S. D. 1953. Studies on root growth in *Acer saccharinum* L. II. Factors affecting root growth when photosynthesis is curtailed. Proc. ned. Akad. Wet., 56: 346-353.

Stone, Edward C. 1955. Poor survival and the physiological condition of planting stock. For. Sci., 1: 90-94.

Wakeley, P. C. 1954. Planting the southern pine. Agr. Monograph No. 18. For. Ser., U.S.D.A., 233 pp.

Wassink, E C. and S. D. Richardson. 1951. Observations on the connection between root growth and shoot illumination in first-year seedlings of *Acer pseudoplatanus* L. and *Quercus borealis maxima* (Marsh) Ashe. Repr. from Proc. Koninklyke Nederlandsche Akademie van wetenschappen (Ser. C), Amsterdam, 54(5): 503-10. For. Abst., 13, No. 3682.

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THE *MIRABILIS*—INSECT COMMUNITY IN ILLINOIS

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Like the human community, the natural communities consist of producers, parasites, predators, scavengers, visitors and vagabonds. In the *Mirabilis*-insect community, as now known in central Illinois, only the producing, predacious and parasitic classes, groups or strata have been observed. However, more extensive and intensive studies, at other times and places, would almost certainly reveal additional classes and species, for the community is not static. The thirteen organisms now known for this community represent four ecological groups. The umbrella-wort, *Mirabilis nyctaginea* (Michx.), Nyctaginaceae, constitutes the primary producing center of the community in that it directly supplies the food and shelter for five phytophagous insects, and indirectly makes possible the life of a predator and six species of parasites that subsist on the phytophags, the latter thus being secondary producers in this organic complex.

Specific Components of the Groups. (1) *Mirabilis nyctaginea,* the primary producing center, or *sine qua non* of the community. (2) Phytophags: *Heliodines nyctaginella* Gibson and *H. ionis* Clarke, Heliodinidae, Lepidoptera; *Celerio lineata* Fabr., Sphingidae, Lepidoptera; *Onychobaris subtonsa* LeConte, Curculionidae, Coleoptera; and *Catorhintha mendica* Stål, Coreidae, Hemiptera. (3) Predator: *Orius insidiosus* (Say), Anthocoridae, Hemiptera. (4) Parasites: *Bracon caulicola* (Gahan) and *B. gelechiae* Ashm., Braconidae; *Tetrastichus coerulescens* Ashm., Eulophidae; *Eupelmus allynii* (French) and *E. cyaniceps* Ashm., Eupelmidae; *Neocatolaccus tylodermae* (Ashm.), Pteromalidae, (all Hymenoptera).

Characteristics of the Species. Although the species composing each group have food preferences in common, each also has distinctive structural characteristics that implement its specific role in the community. The concrete habits and structures that appear to fit each species to perform its own role are described briefly here. More details on certain life histories may be had in the articles by Balduf and Wester, as cited among the references below.

Mirabilis nyctaginea, as the producing center of the community, is well suited to support its phytophagous insect dependents. It is a perennial herb with a fleshy rootstock, sturdy stems and lush ovate leaves. Even the clusters of small pink flowers afford some food to the insects. At least on railroad embankments, where section crews mow it, the plant grows two crops of leaves and seeds annually, in May - June and in August - September, with a period of bare woody stalks intervening. Through the natural spread of seeds and extension of its root system, and especially when

aided by human conveyances, *M. nyctaginea* is capable of rapid spread; this feature accounts for the mobility of the community. In the process of spreading, it is favored by its predilection for well-drained gravelly soil, such as prevails on railroad trackways, where it is now common in Illinois. Indigenous to the Great Plains west of the Mississippi river and the western part of Illinois, its spread eastward began about 1855, when the first railway spanned the river, connecting those new agricultural regions with the populous urban centers along the Atlantic (Balduf, 1957).

The Phytophagous Species of the Community. Catorhintha mendica is unique among the phytophags in being heterometabolous, and that all the stages live exposed on the surfaces of the leaves or branches. Both adults and nymphs feed on plant sap obtained by piercing-sucking mouth parts. Both stages move rapidly on foot, and the adult flies readily. So far as known, *C. mendica* feeds only on *M. nyctaginea,* but possibly also utilizes other species of *Mirabilis,* three of which occur infrequently in Illinois (Jones and Fuller, 1955). It is the only species of the community that Hart (1909) included in his list of all insects found in the sand regions of the Illinois and Mississippi river valleys. Stål (1870) described *C. mendica* from specimens obtained, possibly by Belfrage (Geiser, 1933), from Texas and Mexico. Probably employing its own means of locomotion, it escaped the Great Plains since 1850, moving down the eastbound railroads where its food plant was previously established. It is common wherever *M. nyctaginea* occurs on trackways in Illinois north from Quincy and Urbana, and since Evers (1960) discovered the host plant on railroads south from Madison county, the bug is probably extending its range also in that direction.

Celerio lineata (the white-lined sphinx, Clemens, 1859). In the years 1938-1941, I swept *M. nyctaginea* extensively in Champaign county while making a study of *Catorhintha mendica* (Balduf, 1942). Larvae of *C. lineata* were taken on only two occasions. Five almost full-grown individuals, all about two inches long, were obtained near Tolono on October 5 and 11, 1941, and other large ones near Mahomet, along railroads in both cases. The identifying specialist commented that the larvae are darker than usual. Having a long list of food plants of divers taxonomic relations, this common hornworm is a facultative member of the *Mirabilis* community.

Heliodines nyctaginella. This leaf-skeletonizing micromoth was described by Gibson (1914) from adults reared by Criddle at Aweme, Manitoba, from larvae found feeding on *M. nyctaginea,* "a widely occurring representative of the Nyctaginaceae in Canada." This brief account shows that both the food plant and the insect occur even in the extreme northern part of the Great Plains. I found it commonly on railways in the northern half of Illinois wherever its host occurred. While investigating its life history, Wester (1956) found it in 20 counties across central Illinois. During the seasons of bud clusters, most of the eggs are laid on the outside of

the involucres; otherwise usually on leaves near the top of the plant. Excepting the first instars, the larvae live under webs spun over the clusters of flower-buds and on the leaves. Usually one larva inhabits a web. When it has consumed the tissue, excepting the veins, enclosed by its web, the larva emerges through the opening left at the base of the leaf, crawls down to the next leaf and spins a second web where feeding is resumed. Such changes in location and web-spinning continue until the larva is full-grown, whereupon it apparently descends to debris on the ground for pupation. Wester concluded that the chrypalises of the last, *i.e.* fifth, generation pass the winter.

Heliodines ionis (a stem borer). Previous to the studies by Wester (1954, 1956), only one species of *Heliodines, i.e. nyctaginella,* was recognized from *M. nyctaginea.* He discovered larvae similar to those of *H. nyctaginella* boring in the stems. Moths reared from such larvae by Wester proved to be a new species, which Clarke (1952) named *H. ionis.* It was reported from Champaign, Macoupin and Mason Counties, Illinois, and Wyandotte County, Kansas.

Although the adults are very similar, the two species possess striking differences in habits. *H. nyctaginella* attach their eggs to leaves and clusters of buds, where the larvae develop mostly under webs, then pupate on the ground, and winter as pupae. In contrast, *H. ionis* oviposits in such secluded sites as the paired axial buds, old exits from which previous adults emerged from the stem, and in natural splits in stems. From these positions, the small larvae enter the stems and develop by feeding on the succulent pithy center. When almost full-grown, the borer enlarges its tunnel locally and packs its accumulated excrement in both ends of the enlargement, thereby forming its pupal chamber. But before transforming, the larva lines the chamber with silk and chews a hole through the stem wall to provide for its subsequent exit as an adult. Wester calculated that *H. nyctaginella,* the leaf-skeletonizer, develops five generations in a year as against only three for its boring congener.

Onychobaris subtonsa (a stem borer). Like those of *Heliodines ionis,* the larvae of *O. subtonsa* live as stem borers. However, their activities in relation to the community center differ sharply in several respects. The siphon of *H. ionis* limits it to ingesting free fluids, if it feeds at all, and, lacking a penetrating ovipositor, this micromoth lays the eggs on surfaces. In constrast, the sturdy proboscis of the adult *O. subtonsa,* bearing mandibles at its apex, serves both to feed and as an aid to oviposition. Apparently both sexes feed in the spring on incipient leaves, clusters of flower buds, green seeds and eventually only on the stems (Wester, 1956a). The female places the eggs only in the stems. A pit is prepared with the proboscis for reception of the egg; after the egg is placed, the snout is employed again, probably, in Wester's opinion, to force the egg deeper. Plant sap emanating from the wounded tissue is said to envelope the egg and congeal to form a protective covering.

The young larvae first feed in the epidermis and the cortex of the stem, then tunnel into the pith where they feed until full-grown. Throughout its development, the larva is white, with head light brown, robust, curved and legless. So they are easily distinguished from the above boring lepidopterous larvae. Their last functions are (1) to prepare a pupal cell in the tunnel, employing excrement, and splinters of the woody cortex glued together with excretions from the malphighian tubes, and (2) to chew an exit hole through the cortex to, but not including, the epidermis. From this opening the young adult emerges the following spring. The full-grown larva winters in the tunnel; pupation is delayed until April of the next year. Only one generation is completed annually.

I found *Q. subtonsa* to be common wherever *M. nyctaginea* occurred in the northern half of Illinois and Wester collected it from 16 counties in Central Illinois. LeConte (1876) describes this species from a single specimen taken in Texas by G. W. Belfrage (see Geiser, 1933).

The Entomophagous Species of the Community. The predatory bug, *Orius insidiosus* and the six hymenopterous parasites, reported by Wester (1956b), occurred in small numbers compared with their phytophagous hosts already described above. Both *Orius* and the parasites are facultative in this community since they have previously been shown to utilize also other species of prey and hosts living outside the *Mirabilis* center. (Muesebeck et al, 1951.) This means they have probably entered the *Mirabilis* community from others, where they attacked alternate hosts.

The parasitic forms are equipped with exserted or exsertile ovipositors which enable them to implant their eggs upon or into the host invisible beneath a web or in a tunnel in the stem of *Mirabilis*. Also a high level of sensitivity must be presumed to account for this ability. Previous to oviposition, certain of these parasites inject a venom via the hollow terebra into the host, thus paralyzing it temporarily or permanently, particularly in case of ectoparasites. Wester found that five of the six Hymenoptera are solitary and ectoparasitic on host larvae, *i.e.* a single larva feeds and grows to maturity from the outer surface of a given individual host. Only *Tetrastichus coerulescens* deviates from that pattern of relationship. Here numbers of the larvae develop, all internally. Moreover, the host is not a larva, but the pupa or chrysalis of *Heliodines ionis*. Such are described as gregarious endoparasites.

The host relations and habits of the six species, as reported by Wester (1956b), are briefly summarized herewith.

I. Braconidae.

1. *Bracon caulicola*, solitary ectoparasite on the boring larvae of *Heliodines ionis*, micromoth, and *Onychobaris subtonsa*, snout beetles, in tunnels of *Mirabilis* stems. Host larvae suffer permanent paralysis. Pupation occurs in a cocoon in the host tunnel, and the new adult chews a hole in the tunnel wall for escape.

2. *Bracon gelechiae*. In all bionomic respects like *B. caulicola*, but attacks the advanced larvae of

Heliodines nyctaginella, which live more accessibly under webs on leaves.

II. Eulophidae.

3. *Tetrastichus coerulescens,* a gregarious endoparasite in pupae of *H. ionis* in tunnel of *Mirabilis* stem. Wester believed the adult female enters the host tunnel via the hole chewed in wall of stem tunnel by the host larva, and there parasitizes the mature host. He obtained from 10 to 40 adult *coerulescens* per host pupa.

III. Eupelmidae.

4. *Eupelmus allynii,* a solitary ectoparasite on the boring larvae of *Heliodines ionis* in burrow in stem of *Mirabilis.* The host larva is permanently paralyzed. The parasite winters as a mature larva in the host's burrow, where it also pupates in the spring. The new adults emerge through holes which they chew in the plant stem.

5. *Eupelmus cyaniceps,* a solitary ectoparasite of *H. ionis.* Its relations to the host, also its life cycle, are in all respects as stated above for *E. allynii.*

IV. Pteromalidae.

6. *Neocatolaccus tylodermae,* a solitary ectoparasite on larvae of the black snout beetle, *Onychobaris subtonsa,* in burrow in stem of *Mirabilis.* All hosts previously reported for this species are larvae of snout beetles (Muesebeck, 1951).

7. *Orius insidiosus.* When performing in the *Mirabilis* community, this small predatory bug attacked chiefly the first instars of *Heliodines nyctaginella,* which do not spin a protective web. Both nymphs and adults engaged in the attack. Wester observed them circle around a prospective larva several times, before they rammed it with the extended proboscis and started to feed. Many predatory Hemiptera first employ the forelegs to capture their victims.

Acknowlegments

I am indebted to Dr. Clifford Wester for basic bionomic data on several species concerned in this article. See References Cited.

References Cited

Balduf, W. V. 1942. Bionomics of *Catorhintha mendica* Stål. Bul. Brooklyn Ent. Soc., 37: 158-166.

Balduf, W. V. 1957. The spread of *Catorhintha mendica* Stål. Proc. Ent. Soc. Wash., 59: 176-185.

Clarke, J. F. G. 1952. A new Heliodinid from Illinois. Proc. Ent. Soc. Wash., 54 (3): 138-139.

Clemens, J. B. 1859. Synopsis of North American Sphingidae. Jour. Acad. Nat. Sci. Phila., 4 (ser. 2): 145.

Evers, R. A. and J. S. Winterringer. 1960. New records of Illinois vascular plants. Illinois State Museum, Springfield, Scientific Papers, Vol. 11, pp. 135.

Geiser, S. W. 1933. G. W. Belfrage's Texas localities. Ent. News, 44: 127-138.

Gibson, A. 1914. A new Elachistid moth from Manitoba. Can. Ent. 46: 423-424.

Hart, C. A. 1907. Zoological studies in the sand regions of the Illinois and Mississippi river valleys. Bul. Ill. St. Lab. Nat. Hist., 7: 195-272.

Jones, G. N. and D. G. Fuller. 1955. Vascular plants of Illinois. University of Illinois Press, pp. 593.

LeConte, J. L. 1876. The Rhynchophora of America north of Mexico. Proc. Amer. Phil. Soc., 15: 29.

Muesebeck, C. F. W., C. V. Krombein and H. K. Townes. 1951. Hymenoptera of America north of Mexico. Synoptic Catalog, U.S.D.A., Agr. Monograph No. 2, 1420 pp.

Stål, C. 1870. Enumeratio Hemipterorum. Svenska Vetensk. Akad. Handl., p. 187.

TIETZ, H. M. 1952 The Lepidoptera of Pennsylvania. Penn State College, Agr. Exp. Sta., 194 pp.

WESTER, C. 1954. *Mirabilis nyctaginea* (Michaux) MacMillan and certain insects as a microcommunity. Ph.D. thesis, University of Illinois, Urbana.

WESTER, C. 1956. Comparative bionomics of two species of *Heliodines* on *Mirabilis*. Proc. Ent. Soc. Wash., 58: 43-46.

WESTER, C. 1956a. Notes on the bionomics of *Onychobaris subtonsa* LeConte. Proc. Ent. Soc. Wash., 58: 105-108.

WESTER, C. 1956b. Notes on the bionomics of the natural enemies of the insects on *Mirabilis*. Proc. Ent. Soc. Wash., 58: 283-286.

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THE EFFECTS OF RED AND FAR-RED IRRADIATION ON THE VEGETATIVE DEVELOPMENT OF PEA AND COCKLEBUR

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The vegetative growth of many plants is regulated significantly by light quality and intensity. Several responses are controlled by light quality; these include seed germination, pigment formation, unfolding of the plumular hook, elongation of stems, and leaf expansion. Recent studies have shown that the basic underlying photoreaction involved in each case is the same (Borthwick and Hendricks, 1960; Butler and Downs, 1960; Downs, 1959; Hendricks, 1959; Meijer, 1959). Light is absorbed by a blue-green pigment, phytochrome, which appears to exist in two forms. The photochemical reaction may be written as given below.

$$\text{Pigment } RH_2 + A \xrightarrow{\text{6500-6600 Å max}} \xleftarrow{\text{7200-7400 Å max}} \text{Pigment } FR + AH_2$$

In this formula, *R* and *FR* refer to the red and far-red absorbing pigment forms, respectively (Hendricks, 1959). It has been shown that the effects of red radiation can be markedly reduced or even entirely eliminated in some cases by a subsequent exposure to wavelengths in the far-red portion of the spectrum (Hendricks, 1959; Meijer, 1959; Van der Veen and Meijer, 1959).

The present investigation was undertaken to examine the effects of red and far-red light on certain aspects of the vegetative development of garden pea and cocklebur.

Materials and Methods

Cultural procedure. Seeds of garden pea (*Pisum sativum L.*), variety Thomas Laxton, were soaked for 19 hours in flowing tap water at 8-10°C and then sown approximately 4 cm apart in unglazed clay pots or plastic flats containing vermiculite, thoroughly wetted with tap water. At the end of a germination period of 72 hours in a dark controlled-environment room at 21°C, approximately 50% of the seedlings had emerged. At this time the containers were divided into groups, each containing a minimum of twenty uniform tagged seedlings, and subjected to the various light treatments. The remaining plants in the containers were permitted to grow with the tagged seedlings but were not used in the experiment.

Achenes of cocklebur (*Xanthium pensylvanicum* Wallr.) were germinated by the procedure described by Vergara and McIlrath (1960) and planted approximately 8 cm apart in quartz sand in plastic flats. The seedlings were grown under non-inductive conditions of 20 hours of light per day in a controlled-environ-

ment room at 70±2°F and received approximately 2000 ft-c. of light from General Electric Power Groove fluorescent lamps supplemented with 60-watt incandescent bulbs (approximately 12% of the total wattage). When two nodes became visible, the plants were subjected to the various light treatments. Six plants constituted a series in each treatment.

Both cocklebur and pea plants were watered three times per week during the course of the experiment, the former with a complete nutrient solution (Hoagland and Arnon, 1950) and the latter with distilled water.

Irradiation procedure. All seedlings were exposed to an 11-hour photoperiod between 9 a.m. and 8 p.m. daily. In the six treatment series plants were exposed to various light qualities for the following number of hours: Group A—11 incandescent (I); Group B—9I and 2 far-red (FR); Group C—9I and 2 red (R); Group D—11 fluorescent (F); Group E—9F and 2FR; Group F—9F and 2R. A temperature of 21±2°C and a relative humidity of 60-75% were maintained. When red or far-red light constituted a portion of the treatment, it was always given during the final 2 hours of the light period.

The lamps and filters utilized to produce each type of light regime are indicated in Table 1. The filters were similar to those described by other workers (Liverman, 1959; Na-

TABLE 1.—Light Sources and Energies Utilized in the Various Experiments.

Irradiation	Lamp	Filters	Light Energies, μW/cm²	
			Experiment	
			I	II-III
Incandescent.....	1000-watt incandescent, General Electric, RB 52 (I)*	None	1565	3700
Fluorescent.....	40-watt warm white fluorescent, General Electric (F)*	None	1132	3700
Red.....	40-watt warm white fluorescent, General Electric	Two layers of red cellophane	1827	3700
Far-red.....	1000-watt incandescent, General Electric RB 52	Two layers of red and two layers of blue cellophane	1152	3700

* Percentage spectral energy distribution: 4000-5000 Å — I 10.1, F 19.2; 5000-6000 Å — I 24.1, F 48.8; 6000-7600 Å — I 65.7, F 32.0.

kayama, *et al.*, 1960). The radiant energies for the various types of light were determined with a Weston Illumination Meter (type 756) which had been previously calibrated with a thermopile for each type of irradiation (Van der Veen and Meijer, 1959). The Weston meter readings were taken at the level of the plants. The spectral energy distribution of the visible light from the incandescent and fluorescent lamps (Table 1) was taken from the tables presented by Weitz (1956).

Harvest procedure. The pea seedlings were permitted to grow under the light conditions described for 14 days, at which time the morphological age of the plants in tenths of nodes was determined using a modification of the method of Higgins (1952). This technique is based on scoring the plant's morphological age in terms of number of nodes produced and it permits stages beyond the last discernible node to be designated in tenths of nodes (Figs. 1 and 2).

After the morphological ages of the plants in each group had been determined, the shoots were cut at the level of the cotyledons, and the lengths were recorded to the nearest millimeter of the third internode. The widths of the stipules and leaflets at node five were also determined. The total surface area of the leaflets and stipules at node five was measured with an Aminco leaf area meter.

The length of the second internode of cocklebur was measured to the nearest millimeter. These plants were irradiated simultaneously with the pea seedlings.

Statistical analyses were carried out according to established procedures (Snedecor, 1946).

Results and Discussion

Influence of Quantity and Quality of Light on Internodal Lengths of Pea and Cocklebur. Internodal lengths were greatest when irradiation with either incandescent or fluorescent lamps was followed by far-red radiation (Table 2).

With respect to pea, it is of interest that the multifold increase in light energy during Experiment II, compared with that in Experiment I, had a pronounced effect in the fluorescent series, groups D-F, and a slight but statistically insignificant effect in the incandescent series, groups A-C, (Table 2).

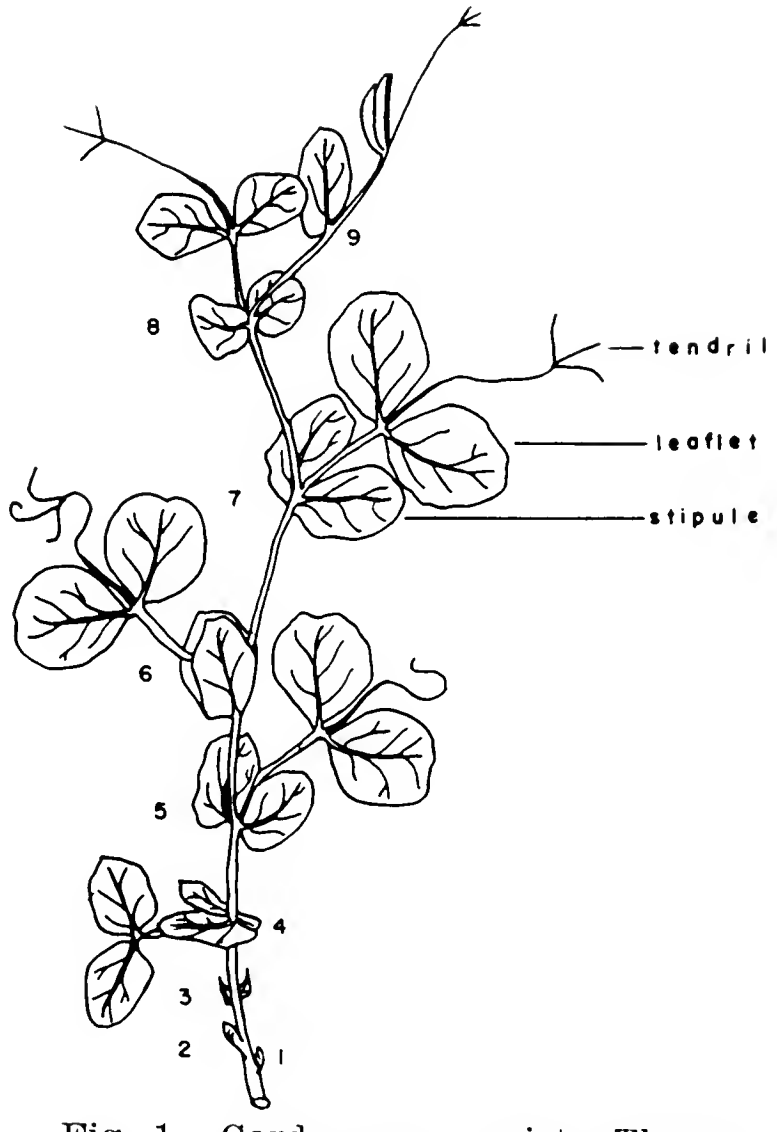

Fig. 1.—Garden pea, variety Thomas Laxton. Nodes are numbered; terminal growing point located between stipules at node 9.

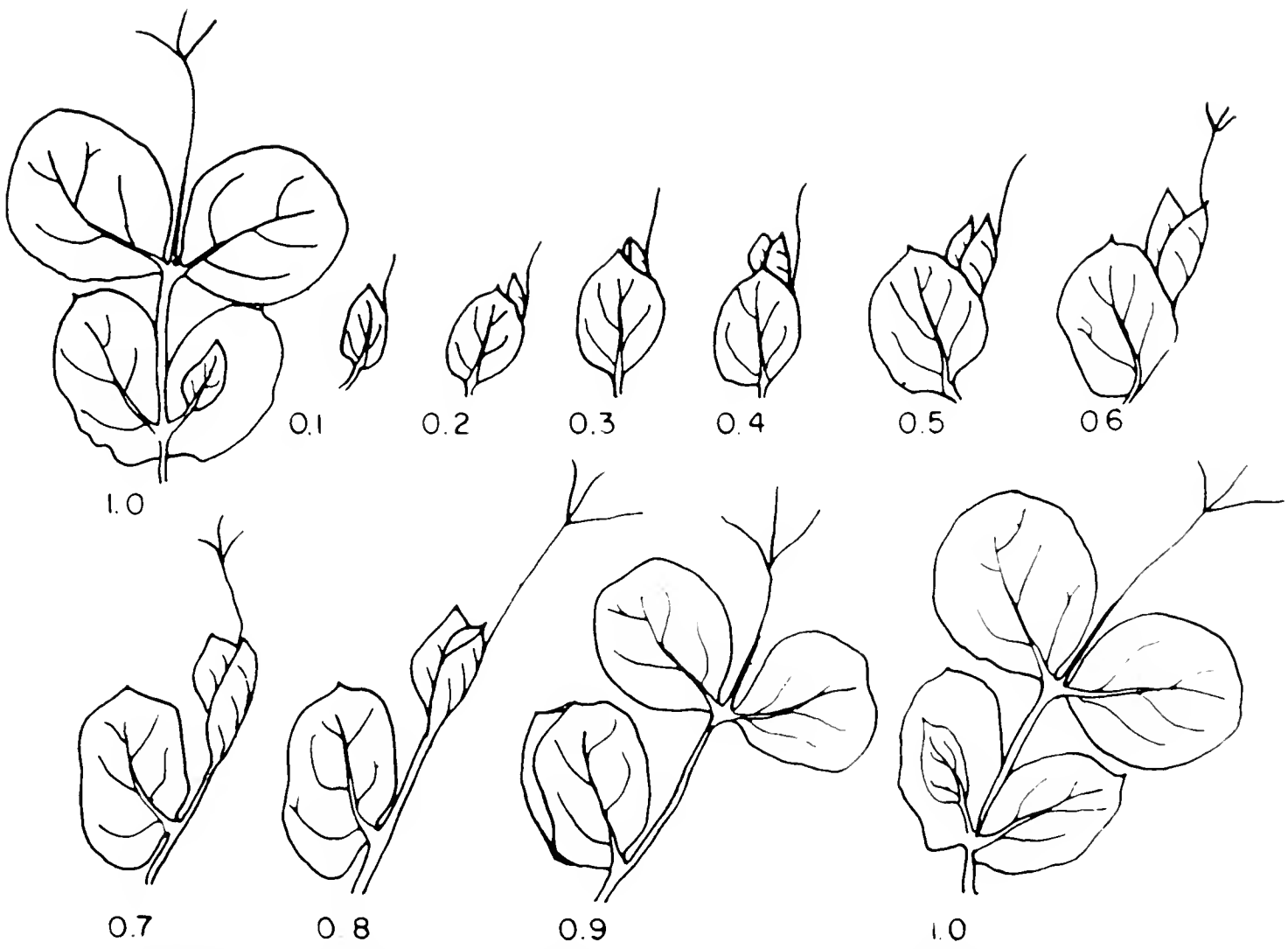

Fig. 2.—Stages in leaf development of garden pea, variety Thomas Laxton. (1.0) illustrates a completed node at the tip of the plant at which point occurs a mature leaf composed of two leaflets, two stipules, and a tendril. Between the pair of stipules is an immature stem which supports a small, tightly closed leaf bud; (0.1) bud develops, increases in size, and the tendril unfolds from between the pair of stipules; (0.2) leaflets, closely held together, begin to show between the stipules; (0.3) leaflets and tendril elongate; (0.4) leaflets separate, both leaflets and tendril elongate; (0.5) separated leaflets and tendril continue to elongate; (0.6) leaflets begin to separate from the stipule; (0.7) leaflets become completely separated from the stipules; (0.8) leaflets begin to unfold, become separated further from the tightly closed stipules; (0.9) leaflets unfold completely, stipule begins to unfold; and (1.0) leaflets and stipules have attained maximum expansion and between the stipules is a tightly closed leaf bud.

The greater energy from the fluorescent light source in Experiment II, as compared with Experiment I, resulted in internode lengths which where 51, 27, and 34 per cent less for plant groups D, E, and F, respectively. The difference in internodal growth of peas at the different light energies under fluorescent and incandescent lamps can probably be explained on the basis of the wavelengths of light emitted by these sources. Fluorescent lamps, with high red and almost no far-red emission, would be expected to maintain the phytochrome system predominantly in the far-red absorbing form and hence less elongation should result (Downs, 1959). In Experiment I, however, internodes were as long or longer in plants grown under fluorescent lamps as in those grown under an incandescent source (Table 2). Apparently the quantity of red light for groups D-F in Experiment I was not sufficient to maintain enough of the pigment in the far-red form to limit elongation. In

Experiment II, however, in groups D-F the increased energy from the fluorescent lamps increased the relative amount of red (and also blue) light received by the plants without any appreciable increment in the far-red, thus maintaining enough pigment in the far-red absorbing form to cause less growth of the internodes. The increased energy in the blue wavelengths may have also been important since Wassink and Stolwijk (1956) have demonstrated that at high energies, in the order of 3700 $\mu W/cm^2$, blue light is very active in inhibiting elongation. In Experiment I, plants subjected only to light from a fluorescent source (group D) were appreciably shorter than those (group F) given such light plus a supplementary treatment of red (Table 2). Incandescent lamps produce considerable red as well as far-red light, and the increased energy from this source in Experiment II for groups A-C did not change the ratio of these two light qualities. Thus one would not expect to get appreciably greater internodal elongation with increased energy from this source, assuming that the initial light energy was not seriously limiting other processes required to sustain growth, such as photosynthesis.

That the pea plants received an appreciable quantity of red light from the incandescent source was apparent from the fact that no significant difference was found in the internodal lengths of plants grown under incandescent lamps with or without supplementary treatment with red light (groups A and C, Experiments I and II) ; plants receiving supplementary treatment of far-red (group B) were, however, significantly different from those (group A) exposed only to light from incandescent lamps (Table 2).

Although no significant differences were found among the internodal lengths of the cocklebur plants exposed to the various incandescent light treatments (groups A-C, Experiment III), the values are in the

TABLE 2.—Effect of Light Treatment on the Length of Internodes of Pea and Cocklebur Plants.

Plant Group	Treatment	Pea Internode 3, mm		Cocklebur Internode 2, mm
		Expt. I	Expt. II	Expt. III
A	I	49.2 ± 1.3	53.3 ± 1.6	111.7 ± 1.7
B	I + FR	57.5 ± 1.7	58.5 ± 1.9	112.5 ± 2.9
C	I + R	52.1 ± 1.8	53.6 ± 1.7	100.2 ± 5.4
D	F	59.1 ± 1.9	29.1 ± 1.2	26.0 ± 1.2
E	F + FR	65.7 ± 2.1	48.2 ± 1.0	87.3 ± 1.8
F	F + R	62.8 ± 1.9	41.5 ± 1.4	24.3 ± 0.4

sequence of magnitude to be predicted if internodal elongation in this species were a red - far-red controlled response (Table 2). The failure of cocklebur plants to show significant differences among the various incandescent treatments, as contrasted with pea, is indicative of the variability among species in responding to a given light treatment.

The difference in internodal lengths of cocklebur plants (Experiment III) grown under fluorescent (group D) and incandescent (group A) lamps was found to be highly significant (Table 2); internodal elongation was drastically curtailed by fluorescent illumination. This inhibition by light from fluorescent lamps, however, was partially overcome by exposure to far-red light; a highly significant difference was evident between group D or F and group E. A supplementary treatment of red light caused a slight but insignificantly greater inhibition of internodal elongation than light from fluorescent lamps alone (Table 2).

Downs (1959), working with loblolly pine, soybean, and tomato, found that longer internodes were produced when the plants entered the dark period with the pigment system predominantly in the red absorbing form which would occur under incandescent supplemental light. Additional work with several varieties of beans further supported the general statement that a brief exposure to far-red radiation before the beginning of the dark period promoted internodal elongation. Meijer (1959) observed that far-red (near infrared) stimulated elongation in Petunia, Calendula, Perilla, Helianthus, bean, and tomato plants. The results with pea and cocklebur plants were consistent with the observations of these workers.

Influence of Quantity and Quality of Light Upon the Morphological Age of Pea Plants. An acceleration of the morphological aging of pea plants resulted from the greater light energy used in Experiment II (Table 3). In the incandescent series, groups A-C, the morphological age was 3.6, 12.0, and 1.8 per cent greater, respectively, in Experiment II than in Experiment I. Greater maturity in the fluorescent groups, D-F, was even more pronounced, the values showing a 10.5, 18.0, and 8.6 per cent increase over those of Experiment I.

Supplemental far-red irradiation not only resulted in longer internodes in pea plants but also depressed the rate of node initiation. This was true whether this light quality followed illumination from incandescent or fluorescent lamps (Table 3). It was slightly more effective, however, when given after light treatment from a fluorescent source. Although supplemental treatment with red light appeared to have a slight influence on the rate of node initiation, statistically it proved to be insignificant.

In the discussion of the influence of fluorescent illumination on internodal length it was pointed out that perhaps the blue light from this source was of importance, for plants grown under fluorescent light only were significantly shorter than plants receiving fluorescent plus a supplemental red-light treatment. With respect to morphological age, however, no significant difference existed between these two treatments, indi-

TABLE 3.—Morphological Age of Pea Plants Expressed as Mean Node Number.

Plant Group	Treatment	Average number of nodes	
		Experiment I	Experiment II
A	I	5.5 ± 0.07	5.7 ± 0.03
B	I + FR	5.0 ± 0.07	5.5 ± 0.03
C	I + R	5.6 ± 0.09	5.7 ± 0.03
D	F	5.7 ± 0.06	6.3 ± 0.10
E	F + FR	5.0 ± 0.08	5.9 ± 0.06
F	F + R	5.8 ± 0.11	6.3 ± 0.10

TABLE 4.—Average Widths of Leaflets and Stipules and Average Area of Leaflets and Stipules at Node Five.

Plant Group	Treatment*	Stipule Width, mm	Leaflet Width, mm	Area of leaflets and stipules, cm^2
A	I	10.4 ± 0.4	16.4 ± 0.5	10.4
B	I + FR	9.5 ± 0.2	13.6 ± 0.7	8.4
C	I + R	11.4 ± 0.3	16.9 ± 0.7	10.8
D	F	13.6 ± 0.4	17.2 ± 0.6	12.0
E	F + FR	12.3 ± 0.4	16.9 ± 0.8	11.7
F	F + R	15.1 ± 0.5	19.6 ± 0.5	12.4

* Plants received light energies of 3700 $\mu W/cm^2$.

cating that blue light was not a determining factor in the rate of node production.

Influence of Light Quality on the Growth of Leaflets and Stipules of Pea. Although in general the widths of the stipules on plants of the fluorescent series tended to be greater than those on plants in the incandescent group, the stipules of plants of group D were not significantly wider than those of group C (Fig. 3; Table 4). Stipule enlargement as a consequence of supplementary irradiation with red light was quite apparent. It was likewise obvious that supplementary irradiation with far-red light inhibited stipule expansion (Table 4).

Red light given subsequent to incandescent illumination appeared to be of little consequence in leaflet expansion, since such supplementary treatment did not result in a signifi-

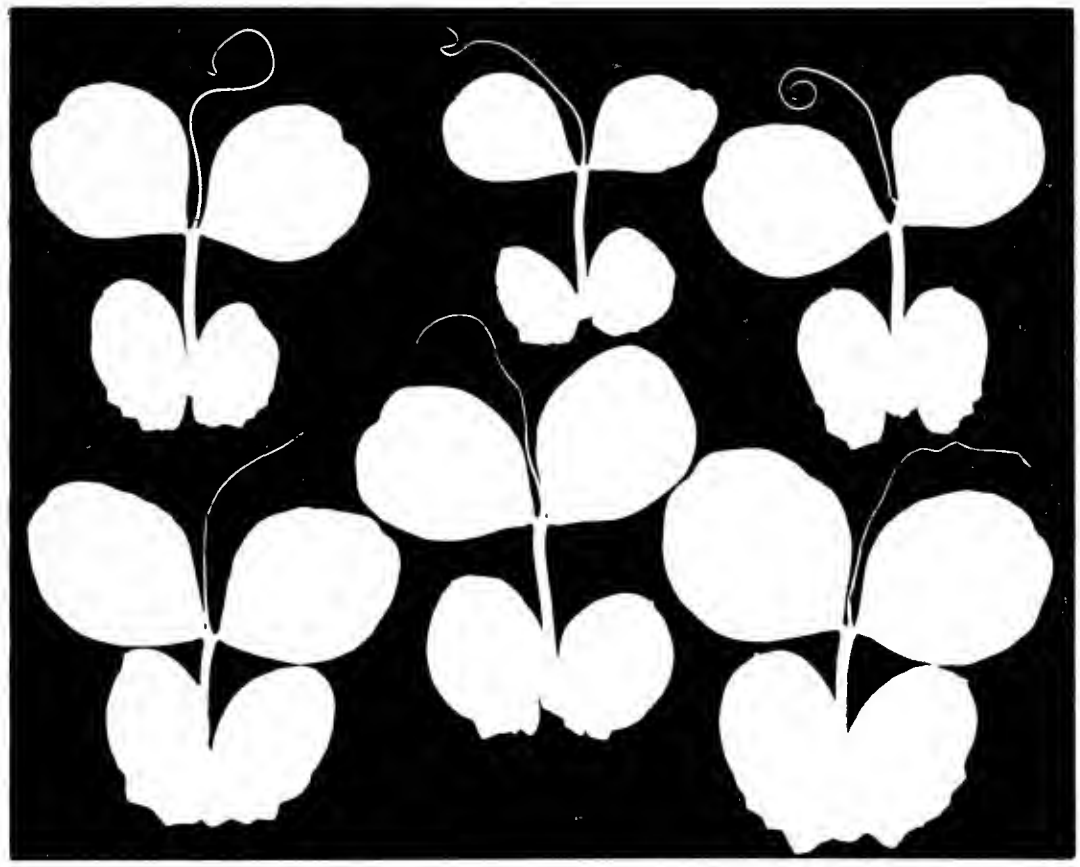

Fig. 3.—Leaf and stipule size at node five. From left to right: top row, groups A through C; bottom row, groups D through F.

cantly greater leaflet width than that which occurred under incandescent lamps (Table 4). A significantly increased leaflet width did result from red light treatment in the fluorescent series, however. With far-red supplementary illumination, on the other hand, significantly narrower leaflets were produced in the incandescent series while no significant effect could be found in the fluorescent group. The reasons are obscure for this apparent red-light effect in the fluorescent group but not in the incandescent series, and also for the far-red effect in the incandescent group but not in the fluorescent series. It is interesting that the stipules responded differently than did the leaflets to the various light treatments.

The area of the stipules and leaflets combined did not show the clear cut relationships exhibited when these organs were considered individually (Fig. 3). This is to be expected in view of the differential responses of these organs to the various light treatments. The general tendency was apparent, however, for the stipules and leaflets to have a greater area when produced under fluorescent rather than under incandescent lamps; under each of these types of illumination these organs exhibited a greater area with red light treatment and a smaller area with far-red illumination.

These results appear to be consistent with the observations of other workers (Liverman, 1959; Parker *et al.*, 1949; Went, 1941).

Summary

Common garden pea (*Pisum sativum* L.), var. Thomas Laxton, and cocklebur (*Xanthium pensylvanicum* Wallr.) plants were grown under various light treatments in 11-hour photoperiods. These included 11 hours of incandescent or warm white

fluorescent, and 9 hours of incandescent or fluorescent followed by a supplementary illumination of 2 hours of red or far-red irradiation. The plants were harvested after a 2-week exposure to the various light treatments. The criteria selected as indices of vegetative growth in pea were internodal elongation, morphological age of plants measured in tenths of nodes, width of stipules and leaflets, and total area of leaflets and stipules. Only internodal elongation was measured in cocklebur.

Internodes were generally shorter on pea and cocklebur plants illuminated with fluorescent lamps only. Exposure to red light following incandescent or fluorescent illumination did not result in significantly shorter internodes, but far-red light following such illumination resulted in significantly longer internodes.

The morphological age of pea plants was greatest for plants grown under fluorescent illumination. Exposure to supplemental red light did not result in a significant increase in morphological age following either fluorescent or incandescent illumination. Far-red light, however, depressed the rate of node initiation significantly under both conditions.

The widths of stipules on plants illuminated with incandescent or fluorescent light alone were significantly different from those given subsequent treatment with either red or far-red light.

The widths of leaflets on plants under incandescent illumination were significantly different from those receiving supplemental treatment with far-red light but not from those receiving red light. For plants receiving fluorescent illumination, the reverse was true.

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Literature Cited

Borthwick, H. A. and S. B. Hendricks. 1960. Photoperiodism in plants. Science, 132: 1223-1228.

Butler, W. L. and R. J. Downs. 1960. Light and plant development. Scientific American, 203(6): 56-63.

Downs, R. J. 1959. Photocontrol of vegetative growth. *In*: Photoperiodism and Related Phenomena in Plants and Animals. R. B. Withrow, editor, Amer. Assoc. Adv. Sci. Pub. No. 55, Wash. D. C., pp. 129-135.

Hendricks, S. B. 1959. The photoreaction and associated changes of plant photomorphogenesis. *In*: Photoperiodism and Related Phenomena in Plants and Animals. R. B. Withrow, editor, Amer. Assoc. Adv. Sci. Pub. No. 55, Wash. D. C., pp. 423-437.

Higgins, J. J. 1952. Instructions for making phenological observations of garden peas. Publications in Climatology. V(2). The Johns Hopkins University Press.

Hoagland, D. R. and D. I. Arnon. 1950. The water-culture method for growing plants without soil. Calif. Agr. Exp. Sta. Circ., 347.

LIVERMAN, J. L. 1959. Control of leaf growth by an interaction of chemicals and light. *In*: Photoperiodism and Related Phenomena in Plants and Animals. R. B. Withrow, editor, Amer. Assoc. Adv. Sci. Pub. No. 55, Wash. D. C., pp. 161-180.

MEIJER, G. 1959. The spectral dependence of flowering and elongation. Acta. Bot. Neerl., 8: 189-246.

NAKAYAMA, S., H. A. BORTHWICK and S. B. HENDRICKS. 1960. Failure of photoreversible control of flowering in *Pharbitis nil*. Bot. Gaz., *121*: 237-243.

PARKER, M. W., S. B. HENDRICKS, H. A. BORTHWICK and F. W. WENT. 1949. Spectral sensitivities for leaf and stem growth of etiolated pea seedlings and their similarity to action spectra for photoperiodism. Am. J. Bot., *36*: 194-204.

SNEDECOR, G. W. 1946. Statistical Methods. 4th ed., Iowa State College Press, Ames, 485 pp.

VAN DER VEEN, R. and G. MEIJER. 1959. Light and Plant Growth. Macmillan Co., New York, 161 pp.

VERGARA, B. S. and W. J. MCILRATH. 1960. Influence of photoperiod on water uptake of *Xanthium*. Bot. Gaz., *122*: 96-102.

WASSINK, E. C. and J. A. J. STOLWIJK. 1956. Effects of light quality on plant growth. Ann Rev. Plant Physiol., 7: 373-400.

WEITZ, C. E. 1956. G. E. Lamps LD-1. General Electric, Cleveland, Ohio, 79 pp.

WENT, F. W. 1941. Effects of light on stem and leaf growth. Am. J. Bot., *28*: 83-95.

WENT, F. W. 1957. Experimental Control of Plant Growth. Chronica Botanica, Waltham, Mass., 340 pp.

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SOME COMPARATIVE ASPECTS OF ORGAN WEIGHTS IN CANADA GEESE (*BRANTA CANADENSIS INTERIOR*)[1]

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Physiological studies of the Canada geese wintering at Horseshoe Lake, Alexander County, Illinois, were initiated in 1954 with a study of organ weights. A series of papers on condition factors (in press), blood chemistry, tissue chemistry, the endocrine organs, nasal glands, and histology of the long bones of the leg are currently under preparation. For background information on the population of geese under discussion, the reader is referred to Hanson and Smith (1950).

Materials and Methods

Organ weights were obtained from 142 geese. The majority of the organs weighed were from geese shot by hunters between dawn and 10.00 A.M. during November and early December.

Prior to weighing the heart, all major blood vessels were excised as completely as possible, and the chambers were cut open and all blood was removed. Spleens were merely freed of excess fascia. The proventriculus was left attached to the gizzard because its function is so intimately related to that of the gizzard and because the juncture of the proventriculus with the esophagus provided a clear-cut margin that could be consistently followed in dissection. All excess fascia and fat attached to the exterior of these organs were removed. They were cut open, rinsed clean of contents, and then excess water was removed by blotting with absorbent paper. Before weighing the liver, the gall bladder was removed, as well as all clotted blood present in the exposed sections of the major veins. The lobes of the pancreas were stripped from the intestine and freed of fat. All weighings were made to one-tenth gram on a triple-beam balance. Age and sex classes of geese were distinguished according to criteria previously presented by Hanson (1949). Immature geese were 5-8 months old, yearlings 17-20 months, and adults 29 or more months of age at the time collections were made. Dr. Horace W. Norton of the College of Agriculture, University of Illinois was consulted on the statistical analyses.

Results

Heart Weights. Weights were obtained of hearts of 142 Canada geese at Horseshoe Lake in late autumn (Table 1). In both sexes a significant absolute increase in heart weight with age is indicated but, as body weight is also higher for each successive age class, there does not appear to be a significant increase in heart weight relative to body weight of age classes except in males

[1] Based on part of a thesis submitted for the Ph.D. degree at the University of Illinois, 1958.

(Table 1). In respect to the correlation of heart weight with body weight, the age-sex class samples proved to be homogeneous; the pooled correlation coefficient was .65 ($P = <.01$). The correlation of heart weight with body weight in each sex-age class was found to be highly significant. Coefficients of variation for heart weights were also the lowest recorded for the five visceral organs studied.

Quiring and Bade (1943) also found the highest correlation of heart-body weight of any organ studied in the house sparrow (*Passer domesticus*). Marsden (1940) found a similarly high correlation for domestic turkeys. Latimer (1927), studying the turkey hen, also found heart weights to have the highest correlation with body weight of the visceral organs. Souba's (1923) data showed a slightly higher correlation of liver weight to body weight than heart weight to body weight in 100 white leghorn cockerels.

The heart weight of the Canada geese studied averaged 0.90 to 0.94 per cent of average body weight. In chickens, heart weight was 0.55 per cent of body weight; in turkeys, 0.53 per cent (Latimer and Rosenbaum, 1926). In white Pekin ducks, heart weight was 0.64 to 0.66 per cent of the body weight (Salgues, 1939). Sixteen passerine species studied by Rensch (1948) had hearts that averaged 0.82 per cent of body weight. Presumably the relatively small heart of domestic chickens, turkeys, and ducks reflects artificial selection and/or their sedentary existence.

Hartman (1955) has reviewed heart weight studies in wild birds and presented much new data for a wide variety of birds. Heart weights varied from 0.2 to 2.4 per cent of body weight. Wide variation was found in the same families of birds. No significant differences were found to be present between age-sex classes, but activity was believed to have an important influence on heart size between species. Mitchell, *et al.* (1926) reported that heart weights in white plymouth rock chickens were higher in cockerels than in both pullets and capons, a difference they attributed to the greater muscular activity of the cockerels. However, it is more likely that these differences, as in the case of pectoral muscles in Canada geese, can be attributed to the nitrogen-conserving effect of the male sex hormones (Hanson, 1961). The relative weight of the heart in Canada geese does not change significantly with age in females despite repeated migrations, but consistently is relatively greater in the older age classes of males than in immatures (Table 1).

Heart weights of white leghorn chickens were also greater relative to body weight in cockerels than in pullets (Mitchell, *et al.*, 1931). Riddle (1947) reported that male ringdoves (*Streptopelia decaocto*) have a slightly larger heart than females, but failed to find a sex difference in the domestic pigeon. Kirkpatrick (1944) found that in both sexes of the ring-necked pheasant (*Phasianus colchicus*) the weight of the heart increased with age.

Smith (1928) concluded that in humans the relative weight of the heart does not increase with age,

TABLE 1.—Heart weights and their relation to body weights in Canada geese at Horseshoe Lake, Illinois in late autumn.

Age and sex	Number	Average weight (grams)	Range (grams)	Per cent of body weight	Standard deviation	Coefficient of variation
Immature male	43	30.0 ± 0.6	22.2-43.0	0.90	4.2 ± 0.5	14.0 ± 1.5
Yearling male	14	36.3 ± 1.2	28.8-43.3	0.94	4.5 ± 0.8	12.4 ± 2.3
Adult male	18	38.2 ± 1.0	32.3-47.7	0.94	4.2 ± 0.7	11.0 ± 1.8
Immature female	34	27.5 ± 0.8	19.2-36.5	0.94	4.4 ± 0.5	16.0 ± 2.0
Yearling female	10	28.4 ± 1.1	23.8-34.8	0.92	3.6 ± 0.4	12.7 ± 1.3
Adult female	23	31.3 ± 0.9	24.6-44.0	0.93	4.3 ± 0.6	13.7 ± 2.0

TABLE 2.—Spleen weights and their relation to body weights in Canada geese at Horseshoe Lake, Illinois in late autumn.

Age and sex	Number	Average weight (grams)	Range (grams)	Per cent of body weight	Standard deviation	Coefficient of variation	Coefficient of correlation
Immature male	43	2.6 ± 0.2	1.1-4.9	0.078	1.1 ± 0.1	38.5 ± 4.1	+0.40
Yearling male	13	2.1 ± 0.2	0.9-3.1	0.054	0.6 ± 0.01	28.6 ± 5.6	+0.14
Adult male	16	2.2 ± 0.3	0.7-5.5	0.054	1.2 ± 0.2	54.5 ± 0.6	+0.49
Immature female	35	2.3 ± 0.1	1.2-4.1	0.078	0.8 ± 0.1	34.8 ± 4.1	+0.05
Yearling female	9	1.7 ± 0.2	0.8-3.1	0.054	0.6 ± 0.1	35.3 ± 8.4	+0.72
Adult female	21	1.1 ± 0.1	0.5-2.6	0.033	0.5 ± 0.1	45.5 ± 7.0	+0.04

irrespective of the weight of the body. The weight of the human heart does, however, increase with increases in weight of the body. In males, the heart is 0.43 per cent of the body weight; in females, 0.40 per cent of the body weight. This latter difference might also be attributable to the differential effect of the sex hormones.

Spleen Weights. The spleens of 137 Canada geese were weighed (Table 2). The spleen in Canada geese tends to decrease in size with age. In immatures and yearlings there is no difference between sexes in the relative size of the spleen; in the adult age class, the males have a markedly larger spleen, both absolutely and relatively. The differentially larger spleens in adult males may reflect an accommodation to the vascular requirements of the more highly developed musculature system of this age-sex class. While size of spleen is not directly related to the red cell count of the blood and hemoglobin level, it is interesting to note that the sex differential in size of the spleen in the adults also corresponds with higher hematocrit and hemoglobin values found for adult males (Hanson, 1958). Harmon, *et al.* (1932) have demonstrated that the spleen of birds apparently can function as a blood reservoir.

The weight of the spleen is extremely variable in Canada geese (Table 2). In nearly all studies of organ weights in chickens and turkeys, the spleen was reported to be the most variable in weight of the visceral organs. Because of the blood reservoir function of the spleen, the variability of spleen weight in Canada geese may reflect the circumstance of death rather than an extreme variability in the mass of the organ tissue *per se*. Geese killed instantaneously may be expected to have a spleen containing more blood than one shot in such a way that its death was in large measure due to loss of blood—whether bleeding occurred internally or externally. Spleen weight in Canada geese tended to be significantly correlated with body weight in males (immatures, $P = .01$; adults, $P = .1 - .05$); in females no significant correlation was found.

Mitchell, *et al.* (1926, p. 126) reported a sex differential in the relative weight of the spleen of white plymouth rock chickens reverse to that found in Canada geese: "The weights of spleen were consistently heavier for pullets than for cockerels." A similar relationship is not evident in their data for white leghorn chickens (Mitchell, *et al.*, 1931).

A highly significant increase in the weight of the spleen in male ring-necked pheasants from 87 to 172 days of age was observed by Kirkpatrick (1944). Spleen weights in captive ringdoves are three times as large in spring and summer as in winter and autumn and the spleens of males are larger than those of females (Riddle, 1929). Opposite seasonal trends in the size of the spleen in ring-necked pheasants have been reported by Kirkpatrick (1944). Male white-crowned sparrows (*Zonotrichia leucophrys gambelii*) have spleens that average larger, absolutely and relatively, than those of the females (Oakeson, 1953). Males of this subspecies attained their lowest average spleen weights in May upon their arrival

TABLE 3.—Combined weight of proventriculus and gizzard and its relation to body weight in Canada geese at Horseshoe Lake, Illinois in late autumn.

Age and sex	Number	Average weight (grams)	Range (grams)	Per cent of body weight	Standard deviation	Coefficient of variation	Coefficient of correlation
Immature male	38	142.5 ± 3.7	114.7-184.5	4.3	22.7 ± 2.6	15.9 ± 1.8	—0.12
Yearling male	9	157.5 ± 5.6	137.0-166.8	4.1	16.8 ± 4.0	10.7 ± 2.5	+0.33
Adult male	7	157.5 ± 11.7	122.1-218.2	4.1	30.5 ± 8.2	19.4 ± 5.2	+0.47
Immature female	28	127.7 ± 2.4	106.0-157.2	4.4	12.9 ± 1.7	10.1 ± 1.3	+0.16
Yearling female	8	144.2 ± 5.9	122.4-163.0	4.7	16.4 ± 4.1	11.4 ± 2.9	—0.06
Adult female	13	140.4 ± 3.3	116.2-157.9	4.4	11.9 ± 2.3	8.5 ± 1.7	+0.49

TABLE 4.—Liver weights and their relation to body weights in Canada geese at Horseshoe Lake, Illinois in late autumn.

Age and sex	Number	Average weight (grams)	Range (grams)	Per cent of body weight	Standard deviation	Coefficient of variation	Coefficient of correlation
Immature male	44	57.8 ± 1.3	40.0- 80.5	1.73	8.9 ± 0.9	15.4 ± 1.6	+0.24
Yearling male	13	55.3 ± 1.7	41.0- 68.8	1.43	6.2 ± 1.2	11.2 ± 2.2	+0.52
Adult male	12	68.0 ± 6.7	50.7- 88.4	1.66	23.5 ± 4.8	34.6 ± 7.1	+0.84
Immature female	37	52.8 ± 1.9	33.0- 89.1	1.79	11.6 ± 1.3	22.0 ± 2.6	+0.29
Yearling female	10	44.7 ± 2.5	25.8-101.1	1.45	8.1 ± 1.8	18.1 ± 4.0	+0.08
Adult female	17	52.5 ± 5.7	36.9-135.7	1.57	23.2 ± 4.0	44.2 ± 7.6	+0.78

in Alaska (Oakeson, 1953). A comparable seasonal trend in spleen weights for a non-migratory race of the white-crowned sparrow (*Zonotrichia leucophrys nuttalli*) was also reported by Oakeson (1956).

Weights of Proventriculus and Gizzard. The weights of gizzards with the proventriculus attached were obtained from 103 Canada geese (Table 3). Second to the heart, the combined weight of these organs was the least variable of those studied. The correlation of the weights of these organs to body weight tended to increase with age, but only in adult females did relationships approach the significant level ($P = .1$).

As the proventriculus accounts for a relatively small per cent of the combined weight of this organ and the gizzard in Canada geese, it is evident from their combined relative size, 4.1 to 4.7 per cent of the body weight, that the gizzard in this species is large. These data suggest that the Canada goose is adapted to feeding on relatively coarse, indigestible foods as well as tender stems and leaves of grasses, sedges, and domestic forage crops. For example, prior to the establishment of the Horseshoe Lake Refuge, the Canada geese which then wintered along the Mississippi River utilized the bark and cambium of the willow shoots growing on the river bars. When food is not readily available on the Horseshoe Lake Refuge, the geese will enter woodlands and eat acorns. In northern Ontario in early spring while there is still a deep snow cover and little food available, the furry catkins of willows are sometimes taken.

Latimer and Rosenbaum (1926) found the gizzard to be the least variable ($V = 6.35$) of the visceral organs of the hen turkey. In turkeys, the gizzard forms 2.4 per cent of the body weight; in chickens, the gizzard forms 2.1 per cent (Latimer and Rosenbaum, 1926). Mitchell *et al.* (1926, p. 109) have stated regarding white leghorn chickens that "the females consistently exceeded the males in weights of gizzard," a finding which the present data on Canada geese support. The gizzard of the starling (*Sturnus vulgaris*) averages 2.79 and 2.97 per cent of the body weight for males and females respectively (Stegman, 1954).

Liver Weights. Liver weights were obtained for 133 Canada geese (Table 4). In autumn, the liver averages higher in absolute weight in males than in females, but when compared on the basis of body weight there were no significant differences. In both sexes, the relative weight of the liver in immatures was markedly higher than in the older age classes, but in both sexes it was relatively greater in adults than in yearlings. However, in adults, the liver is notably more variable in size than in the younger age classes. The best estimates that could be made of the correlation of liver weight to body weight (data pooled by the method of least squares, using the z transformation) were .12 for immatures, .51 for yearlings and .77 for adults, no difference between the sexes being found. While the significance of the values for immatures is nil, the correlation coefficient increases with age and in the adults the values are highly significant

($P = .01$). These comparisons between age-sex classes are considered valid because nearly all of the geese studied were shot by hunters in the morning before the geese had much opportunity to feed. Liver weights of Canada geese at other times of the year will be reported by Hanson (1961, in press).

Marsden (1940) found no significant correlation of liver weight to body weight in a sample of ten turkeys studied. The livers of 12 bronzed turkey hens studied by Latimer and Rosenbaum (1926) composed 2.25 per cent of the body weight as compared with 2.40 per cent for chickens. The coefficient of variability for liver weight in these turkeys was 29.5.

A highly significant correlation of liver weight to body weight in white leghorn cockerels was reported by Souba (1923). Mitchell, *et al.* (1931) found that in white leghorn cockerels between 0.5 and 5.0 pounds, the liver decreased from 3.36 to 2.15 per cent of body weight with increasing body weight. In pullets between 0.5 to 4.0 pounds, the relative weight of the liver decreased from 2.98 to 1.89 per cent of body weight. Between the weights of 0.5 and 7.0 pounds, the livers of cockerel plymouth rock chickens decreased from 3.7 to 1.3 per cent of body weight with increasing body weight; in pullets weighing from 2 to 5 pounds, the liver decreased from 2.5 to 1.9 per cent of body weight (Mitchell, *et al.*, 1926).

Mitchell, *et al.* (1931, p. 107) have stated that "Beyond the 1.5 pound weight, white leghorn pullets possessed a larger average weight of digestive apparatus, both absolute and relative, than the cockerels." They found a decrease in the weight of the viscera with age, particularly in the younger age groups, noting (p. 136) that "The cockerels were clearly distinguished from the pullets by a more rapid decrease in the percentage weight of the digestive tract." The data presented in this paper for the visceral organ weights of Canada geese reflect these same general trends.

It is generally recognized that small animals have proportionately larger organs than large animals (Rensch, 1948). The heart weight of geese appears to be exceptional in this respect, but liver weights are consistent with the rule. Most of the 46 species of small birds (largely passerines) studied by Rensch (1948) had livers that ranged from 3 to 5 per cent of body weight. A single swan (*Cygnus olor*) studied had a liver weight equal to 1.85 per cent of body weight. Liver weights constituted 2.7 to 2.9 per cent of body weight of Pekin ducks (Salgues, 1939) and 5.01 to 5.02 per cent of body weight of the European starling (Stegman, 1954).

The liver weights of migratory white-crowned sparrows (*Zonotrichia leucophrys gambelii*) increased from November through April, highest and lowest values coinciding with the beginning and ending of migration (Oakeson, 1953). The pattern of liver weight change in the nonmigratory race (*Zonotrichia leucophrys nuttalli*) was essentially the same as in the migratory race (Oakeson, 1956). Female ringdoves 15 to 18 months of age have a significantly larger liver than males, and both sexes show an increase of liver

TABLE 5.—Pancreas weights and their relation to body weights in Canada geese at Horseshoe Lake, Illinois in late autumn.

Age and sex	Number	Average weight (grams)	Range grams)	Per cent of body weight	Standard deviation	Coefficient of variation	Coefficient of correlation
Immature male	42	12.8 ± 0.5	6.4-21.6	0.39	3.6 ± 0.4	28.0 ± 3.1	—0.10
Yearling male	10	11.6 ± 0.9	6.4-15.6	0.30	2.7 ± 0.6	23.6 ± 5.3	+0.49
Adult male	12	10.9 ± 0.6	7.4-14.0	0.27	2.1 ± 0.4	19.3 ± 3.9	—0.55
Immature female	34	12.1 ± 0.7	5.8-26.6	0.41	4.3 ± 0.5	35.3 ± 4.3	+0.16
Yearling female	9	10.5 ± 0.7	6.2-13.9	0.34	2.2 ± 0.5	21.0 ± 5.0	+0.04
Adult female	12	10.0 ± 0.7	6.0-17.2	0.32	2.5 ± 0.5	25.3 ± 0.5	—0.10

weights in summer (10.4 per cent in males, 6.1 per cent in females) over winter weights (Riddle, 1928). In a later study, Riddle (1947, p. 122) stated that "In both ring doves and pigeons the livers of females are relatively (usually also absolutely in doves) heavier than those of males. In data from doves this excess averaged 10-14 per cent; in pigeons it was somewhat smaller and more variable."

Pancreas Weights. The weights of the pancreases of 119 Canada geese were obtained (Table 5). The data indicate that pancreas weight declines slightly with age, both absolutely and relatively, and that relatively, the females have a slightly larger pancreas than males. However, no significant correlation between pancreas weight and body weight was found within any age-sex class.

The pancreas is a highly variable organ in birds, being second only to the spleen in this respect. Studies of pancreas weight in chickens by Oakberg (1949) and in turkeys by Latimer (1927) and Marsden (1940) showed no significant correlation between pancreas weight and body weight. However, Souba's (1923) data on 100 white leghorn cockerels indicate a highly significant correlation between pancreas weight and body weight. Perhaps this may be explained by the sample being highly uniform in age and uniformity of the experimental conditions. According to Salgues (1939), the pancreas of Pekin ducks constitutes 0.22 per cent of the total body weight in males and 0.26 per cent in females, values that are considerably lower than for Canada geese. Latimer and Rosenbaum (1926) give 0.15 and 0.20 as values for the turkey hen and chicken respectively. Values for the white plymouth rock and white leghorn chickens given by Mitchell, *et al.* (1926, 1931) are similar to those for the Pekin duck.

Summary

Heart weight was the least variable of the visceral organs of Canada geese and showed the highest correlation with body weight. The spleen was the most variable of the five organs weighed. In respect to body weight, the weight of the spleen of adult males was markedly greater than that of adult females. The proventriculus and gizzard, particularly the latter, were found to be remarkably large in Canada geese, constituting 4.1 to 4.7 per cent of body weight. Liver weights averaged between 1.43 and 1.79 per cent of body weight, values for immatures being highest and those for yearlings lowest of the three age classes. No correlation between liver weight and body weight was found for immatures; in adults the correlation was highly significant. The weight of the pancreas was highly variable and showed no significant correlation with body weight. In most respects, organ weight relationships in Canada geese showed good agreement with findings for other species of birds.

Literature Cited

Hanson, Harold C. 1949. Methods of determining age in Canada geese and other waterfowl. Jour. Wildl. Mgmt., 13: 177-183.

HANSON, HAROLD C. 1958. Studies on the physiology of Canada geese (*Branta canadensis interior*). Ph.D. thesis, University of Illinois, 125 pp.

HANSON, HAROLD C. 1961. The dynamics of condition factors in Canada geese and their relation to seasonal stresses. Arctic Institute of North America, *In press.*

HANSON, HAROLD C. and ROBERT H. SMITH. 1950. Canada geese of the Mississippi Flyway, with special reference to an Illinois flock. Ill. Nat. Hist. Surv. Bull., 25: 67-210.

HARMON, I. W., E. OGDEN and S. F. COOK. 1932. The reservoir function of the spleen in fowls. Am. Jour. Physiol., 100: 99-101.

HARTMAN, FRANK A. 1955. Heart weight in birds. Condor, 57: 221-238.

KIRKPATRICK, C. M. 1944. Body weight and organ measurements in relation to age and season in ring-necked pheasants. Anat. Rec., 89: 175-194.

LATIMER, HOMER B. 1927. Correlation of weights and lengths of the body, systems and organs of the turkey hen. Anat. Rec., 35: 365-377.

LATIMER, H. B. and J. A. ROSENBAUM. 1926. A quantitative study of the anatomy of the turkey hen. Anat. Rec., 34: 15-23.

MARSDEN, S. J. 1940. Weights and measurements of parts and organs of turkeys. Poul. Sci., 19: 23-28.

MITCHELL, H. H., L. E. CARD and T. S. HAMILTON. 1926. The growth of white plymouth rock chickens. Univ. Ill. Agr. Exp. Sta. Bull., 278: 71-132.

MITCHELL, H. H., L. E. CARD and T. S. HAMILTON. 1931. A technical study of the growth of white leghorn chickens. Univ. Ill. Agr. Exp. Sta. Bull., 367: 83-139.

OAKBERG, E. F. 1949. Quantitative studies of pancreas and islands of Langerhans in relation to age, sex and body weight in white leghorn chickens. Am. Jour. Anat., 84: 279.

OAKESON, BARBARA B. 1953. Cyclic changes in liver and spleen weights in migrating white-crowned sparrows. Condor, 55: 3-16.

OAKESON, BARBARA B. 1956. Liver and spleen weight cycles in non-migratory white-crowned sparrows. Condor, 58: 45-50.

QUIRING, DANIEL P. and PAUL H. BADE. 1943. Organ and gland weights of the English sparrow. Growth, 7: 299-307.

RENSCH, BERNHARD. 1948. Organ proportionen und Korpex grosse bei Vogeln und Saugetieren. Zoologische Jahrbucher. Abteilung. fur Allgemeine Zoologie und Physiologie, 61: 337-412.

RIDDLE, OSCAR. 1928. Sex and seasonal differences in weight of liver and spleen. Proc. Soc. Exp. Biol. and Med., 25: 474-476.

RIDDLE, OSCAR. 1929. Endocrine regulation of reproduction. Endocrin., 13: 311-319.

RIDDLE, OSCAR. 1947. Endocrines and constitution in doves and pigeons. Carnegie Inst. of Wash., Publ. No. 572., 306 pp.

SALGUES, R. 1939. Contributions nouvelles a la physiologie de la plume F. L'osteomalaise aviare et ses repercussions sur le plumage. L'Oiseau et la revue Francais d'ornithologie. New Series, 9: 33-51.

SMITH, H. L. 1928. The relation of the weight of the heart to the weight of the body and of the weight of the heart to age. Am. Heart Jour., 4: 79-93.

SOUBA, A. J. 1923. Variations and correlation of the organs of single comb white leghorn cockerels. Anat. Rec., 26: 291-297.

STEGMAN, LEROY. 1954. Variation in a flock of the European starling. Auk, 71: 179-185.

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JUNIOR ACADEMY PUBLICATIONS

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The Illinois Junior Academy of Science, since its formation, has been a major project of the State Academy of Science. In recent years the Junior Academy has had a substantial growth. The success of the district and state science expositions, which testifies to the increasing interest among junior and senior high school students, has prompted the Council of the Academy to explore additional means of assisting in the development of young scientists. To this end a publication program was approved.

A limited number of Junior Academy papers will be published in an appropriately designated section of the Transactions of the Illinois State Academy of Science. There are two methods by which a student's paper can be submitted for consideration, but in either case the manuscript must conform to acceptable standards. Source material must be properly documented, references and citations accurately given in accordance with the style currently in use in the Transactions, and the text typed double spaced. Illustrations should be used only where essential and must be prepared so that they can be clearly reproduced within the limitations of the page size. The student's name and school should be accompanied by his home address so that he can be contacted for necessary editorial changes.

The first method of submitting a paper for possible publication is by way of the paper sessions of the State meeting of the Junior Academy. The highest ranking papers at the State meeting will automatically be given consideration.

The second method is by sponsorship by a member of the State Academy of Science who has personal knowledge of the project. Although any member of the Academy may serve as such a sponsor, it is preferred that the teacher under whom the student is working be the sponsoring member. In such cases the sponsor should send the manuscript, accompanied by a supporting letter of transmittal, directly to the Editor of the Transactions.

It is unfortunately true that limitations of space make it likely that it will not be possible to publish all of the worthy papers. Final decision for acceptance for publication rests with the Editor of the Transactions and his Editorial Board.

THE HATCHING MUSCLE IN THE AMERICAN COOT

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It is believed that a young bird hatches by using a muscle which exends from the neck to the middle of the back of the head. This muscle increases in size during development but most rapidly just before hatching. After hatching, it decreases in size. In grown birds the muscle, although relatively small, is used for other purposes. Inside the egg the embryo is so positioned with its bill against the shell, and with the neck curled, that it can use this muscle to extend the head and bill upward to pip the egg and eventually hatch out.

There has been some work done on this muscle in the chicken (Keibel, 1912; Pohlman, 1919; Fisher, 1958), in North American grebes (Fisher, 1961a) and in Franklin's Gull (Fisher, 1961b). The work of Fisher supports this idea of hatching, as outlined above.

My purpose in this paper is to point out and explain the phases of the gross development of this muscle in the American Coot, *Fulica americana*, from the time the embryo weighs just a few grams to the age of two weeks.

Materials and Methods

One hundred fifty-eight eggs were taken from nests in the Delta Marshes at Delta, Manitoba, Canada. Immediately upon return to the Delta Waterfowl Research Station, the eggs were incubated, usually within two or three hours of collection. The eggs in each clutch were numbered and the clutches kept separate in the incubator. Incubation was at 99.5 degrees F and from 60 to 70% relative humidity. The young coots were removed from the incubator at one day of age and kept in indoor pens. Their food was a high-protein, turkey pre-starter mix. An abundance of water was supplied for drinking and swimming. Never were more than seven or eight young coots kept in any one pen.

Since the female coot lays one egg each day and starts incubating upon the laying of the first egg, the eggs in any one clutch were in different stages of development at the time of collection. It was thus not possible to age the embryos by backdating from the time the first egg hatched. Sometimes two eggs in the same clutch hatched on the same day. For these embryos which were not permitted to complete their development I used body weight as an index to the stage of development. After hatching, both age and weight were used to indicate development. I attempted to get a series of embryos representing all weight stages.

Removal of unhatched embryos was done within 30 minutes of removal of the egg from the incubator. The egg was cracked on a line around the end containing the air pocket so as not to damage the specimen in any way and to permit examination

of the position of the head. The membranes were removed from the embryos, including the yolk sac in embryos in which it had not yet been completely drawn into the body. The embryos were dried by gently rotating them on paper towels for not more than one minute. After drying, the embryos were weighed on a balance to the nearest tenth of a gram. The muscles were removed with iridectomy scissors and weighed immediately on a Roller-Smith Precision Balance to the nearest ten-thousandth of a gram. The birds were then preserved in formalin for later study of the egg-tooth.

The thickness of the egg shell was measured at two different places on the edge of the breakage line of eggs which had produced normally-hatched young. A dial micrometer, calibrated to thousandths of an inch, was used.

Results

Segmentation begins to appear faintly at approximately the 7-gram stage of embryonic development. Segments are definitely visible by the 9-gram stage and are in all cases visible throughout incubation. But just before hatching the segments may be difficult to see because of the large lymph content of the muscle. Segmentation gradually disappears after hatching. At six or seven days of age it is very faint, and in many specimens is not visible thereafter. In some embryos only parts of the posterior and anterior boundaries of the individual segments remain.

The development of segmentation starts anteriorly (Fig. 1). The anterior segment appears first and is the largest throughout the history of the muscle. The posterior segment is always the smallest. Usually three pairs of segments are present before hatching. In only one instance was there any variation in the number of segments; one chick had a slight enlargement of a fourth pair of segments.

The first medial contact between segments of opposite sides is between the anterior pair; this is the condition in one-fourth of the 6-gram specimens. By the time the embryos reach 7 grams in body weight most show medial contact at least between the first pair of segments. At the 8- or 9-gram stage the medial contact has proceeded posteriorly to include the first two pairs of segments in approximately 50% of the specimens. There is medial contact between the first two pairs by the prepip stage in most specimens. And some individuals also have limited contact between the anterior parts of the third pair of segments. After hatching there is a progressive decrease, from posterior to anterior, in the amount of medial contact, until at 17 days of age only part of the inner margins of the first pair are touching (Fig. 1).

The muscle increases in absolute weight from 0.020 grams at 8 grams of body weight to 0.24 grams at 15 grams of body weight, at which time the embryo is ready to pip. Muscle weight decreases from the pipping stage, when it weighs 0.16 grams, to approximately 0.05 or 0.07 grams at two or three days of age. After this it slowly increases in weight.

There are two times in development when the muscles are very large, if the muscle weight is com-

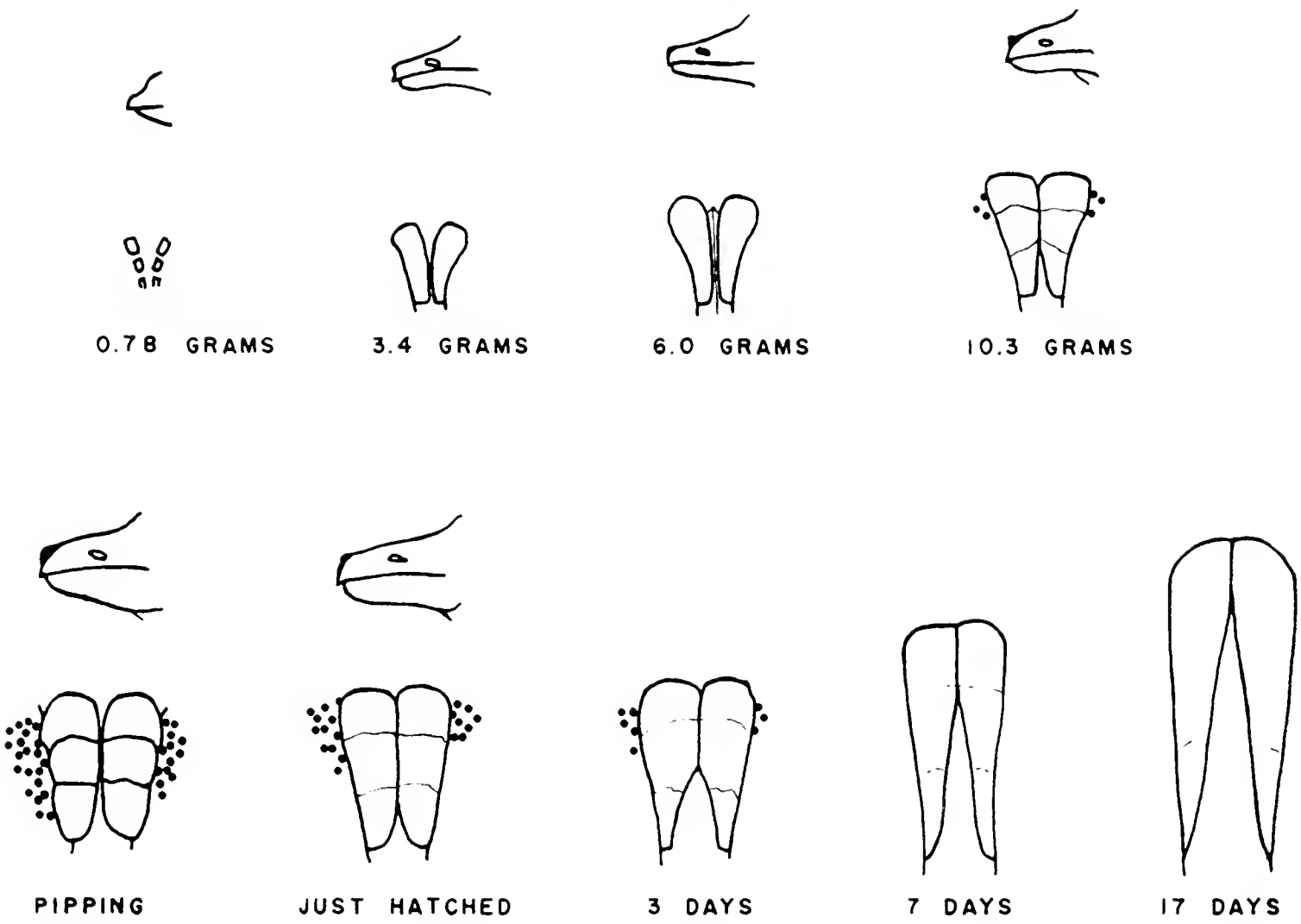

Fig. 1.—Diagrams of development of the egg tooth and hatching muscle in the American coot. Weights refer to body weights.

puted in relation to body weight (Fig. 2). The first time is at the 4-gram stage or earlier when the muscle constitutes about 1.56% of body weight. The second time is between the body weights of 13 and 16 grams. The first instance is due to the more rapid development of the anterior part of the embryo. The latter time is during the prepip stage. As the development progresses from the 4-gram stage, the muscle weight becomes relatively less until about the 7- or 8-gram stage when the muscle may make up as little as 0.2% of body weight (Fig. 2). During the rest of the incubation period weight increases rapidly, in relation to body weight, and reaches a maximum of 1.64% of body weight. During the pipping period the muscle begins to decrease very rapidly in weight, and this continues through the second day of age. Beginning at about the third day of age the decrease in relative weight becomes more gradual and continues to decline at least until 14 days of age. At five or six days of age the muscle is about the same relative size as it was when the embryo weighed only 7 or 8 grams.

The lymph glands situated on either side of the pair of muscles on the neck are believed to have some influence on the action of the muscle. It is known that they produce lymph which moves into the muscle, and Pohlman (1919) states that this hinders the action of the muscle. H. I. Fisher (1961a) believed that this infiltration of lymph may ac-

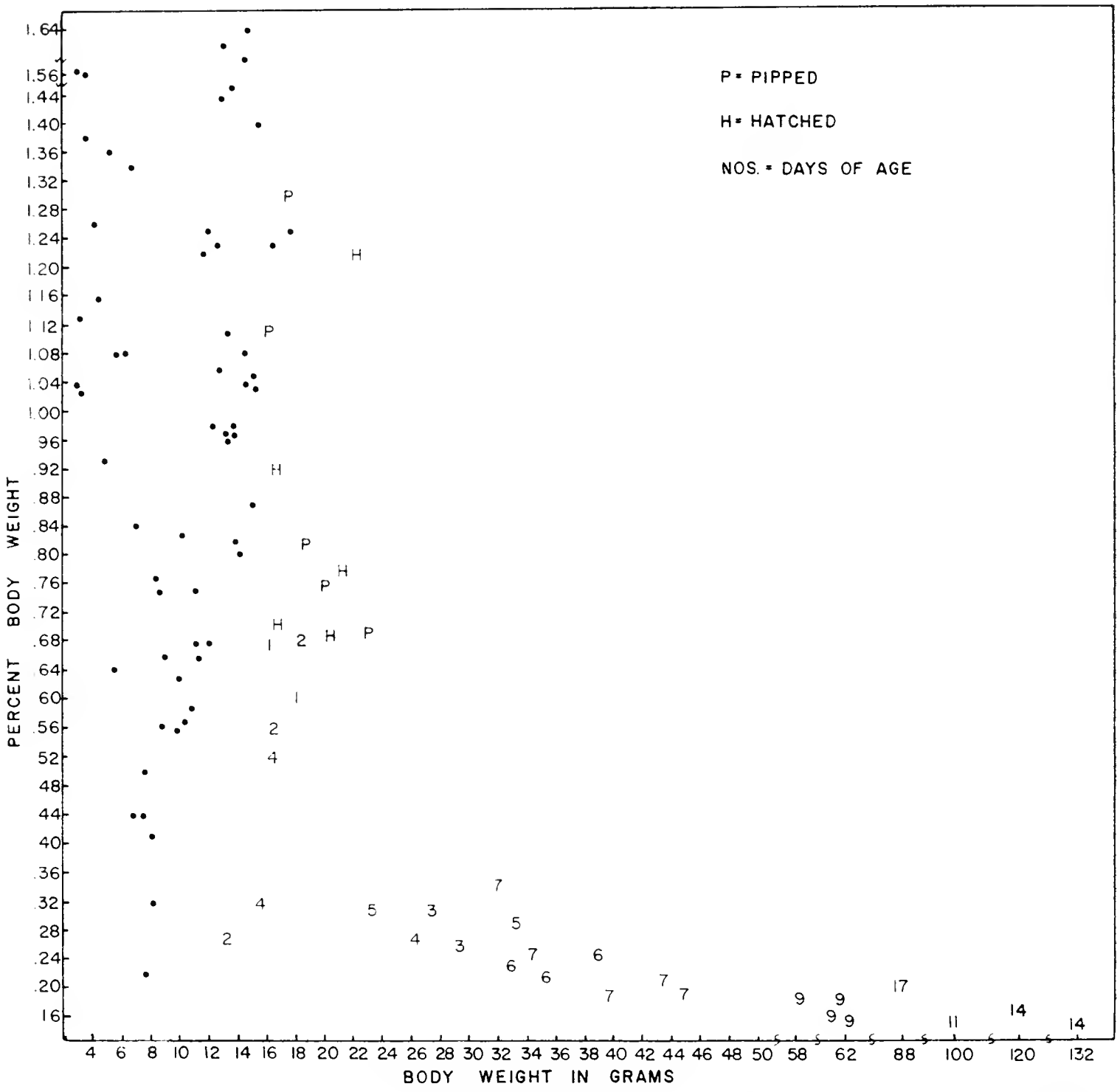

Fig. 2.—Scattergram to illustrate changes in relative size of the hatching muscle in the American coot.

tually help the action of the muscle, perhaps through the provision of fats and sugars for energy. Because of these varying views the lymph glands will be discussed in this paper.

The lymph glands are not grossly apparent before the embryo reaches 7 grams of body weight, and of 21 specimens, 3 days or more of age, the glands were completely absent or too small to measure in 12. There is not much change in the dimensions of the glands between the 7-gram and 16- to 18-gram stages. At the latter time the width decreases and the glands become more elongate. During the pipping process the glands become thin and string-like.

The lymph glands frequently consist of scattered lobes or kernels. This scattered condition may appear at any stage, but it is less frequent in the pipping and hatching stages. Triangularly shaped glands occur in

about 8% of the birds prior to hatching, but are not seen after hatching.

In only 4 of 97 birds were the glands absent or less than 1 mm. in diameter on one side or the other. There was no difference in the frequency of occurrence or in size between the glands of the two sides.

I noted earlier that the muscle has a large lymph content. This results in a clear to yellowish "lymph color", as I shall call it; lymph color first appears in the muscles at the 9-gram stage, but only to a slight degree and only in 50% of the specimens. When the 13-gram stage is reached nearly all the specimens show a strong lymph color which continues through the hatching period. In this period the muscle appears lymph-filled, a condition which appears in only about one-fourth of the specimens at the 12-gram stage. Lymph-filled muscles were never found in specimens more than 12 hours of age, but the muscles retain a pinkish-yellow color until about the 3-day stage when the "normal" reddish color begins to appear. By 5 to 7 days after hatching, the muscles are reddish.

Since the development of the egg-tooth, as a part of the body aiding in hatching, is related to the development of the hatching muscle, I shall indicate here a few of the more obvious stages. The smallest embryo in which I could find any indication of an egg-tooth weighed 0.78 grams. There is a definite bump on the end of the bill by the 3-gram stage, and by 10-grams in body weight this protuberance is pointed upward and forward (Fig. 1). The egg-tooth is largest at the time of pipping. It diminishes in size very rapidly in the later stages of pipping and immediately after hatching. There is no evidence of an egg-tooth after three days of age.

Since there may be a relationship between the size of the muscle and the thickness of the shell, I shall give here the measurements of the thickness of the zone of breakage during hatching. In 34 eggs this averaged 0.0105 ± 0.0001 inches, with a range from 0.0095 to 0.0122 inches.

Discussion and Summary

Development of segmentation in the hatching muscle is the same in coots as in the chick (Keibel, 1912, Pohlman, 1919, Fisher, 1958) and in the Franklin's Gull (Fisher, 1961b). Segments or blocks of tissue which will form the muscle first appear distinctly to the unaided eye at the 0.5-gram stage. The first segments in the formed muscle appear at 7 grams, are definite by the 9-gram stage, and consist of 3 pairs in most instances. A 4th segment was observed more often in the North American grebes (Fisher, 1961) than in the coots. The development starts anteriorly and progresses toward the posterior. Thus the anterior segments are the largest and the posterior segments are the smallest.

Segmentation is not visible in some birds after 6 or 7 days of age and only traces of the segmental boundaries remain visible in others. The first medial contact becomes visible between the anterior pair of segments. The area of contact increases between other segments, reaching the 3rd pair just before hatching. After hatching, the line of medial contact

decreases progressively. This same developmental pattern was noted in the above literature.

Absolute weight of the muscle in the coot increases from the 8-gram stage of body weight to the pipping stage. Once the chick is hatched, the weight of the muscle decreases for a few days and then starts to increase again. There is no apparent decline of the weight during or after hatching in the grebes, but the data were few.

Relative weight is great at first observation; it then decreases until the 8-gram stage. During the rest of the incubation period the weight increases relatively, up to the prepip and pipping periods when it starts to decline rapidly. This decrease is more gradual from about 3 days to at least 14 days of age.

There is not much change in the size of the lymph glands from the time they first become apparent, when the bird weighs 7 grams, until it weighs 16 to 18 grams. The width decreases and the glands become string-like at 16 to 18 grams when the chick is pipping. These glands are absent after approximately 3 days of age. Although there are no visible lymph glands in the area of the muscle of the North American grebes, Fisher (1961a) said there is an obvious infiltration of lymph. In the Franklin's Gull (Fisher, 1961b) the glands start to elongate at 10 grams. This elongation increases more rapidly than the width, reaching its maximum just after hatching.

The color of the muscle is changed by the infiltration of the lymph. This "lymph color" first appears at 9 grams in 50% of the specimens. It then increases in amount and number of specimens in which it is visible, showing strong lymph discoloration up through hatching. After 12 hours of age the muscle slowly returns to its normal reddish color.

The egg-tooth first appears at 0.8 grams of body weight and grows larger and more pointed up to pipping. During pipping and hatching the egg-tooth decreases in size. There is no sign of it after three days of age.

Thickness of the egg shell at the time of hatching was 0.0105 ± 0.0001 inches.

Success in maintaining and raising young coots, which has been very difficult in the past, was thought to be mostly the result of three factors: (1) putting newly hatched young in with a few older birds (ducks or coots) that were feeding successfully; (2) allowing at least five square feet for each young bird in the pen; and (3) using a very high protein diet.

Acknowledgments

I am grateful to Mr. Albert Hochbaum, Director, Delta Waterfowl Research Station, Delta, Manitoba, Canada, who gave me permission to collect eggs and coots on the research station area and who also provided the space and facilities to carry out the research for this paper. Many thanks go to my father for his constant help and advice in the laboratory and field. To my mother I am indebted for aid in collecting eggs which were badly needed.

Literature Cited

Fisher, Harvey I. 1958. The "hatching muscle" in the chick. Auk, 75: 391-399, 12 figs.

———— 1961a. The hatching muscle in North American grebes. Condor, 63(3): 227-233, 4 figs.

———— 1961b. The hatching muscle in Franklin's Gull. Wilson Bull., *in press*.

Keibel, Franz. 1912. Wie zerbricht der ausschlüpfende Vogel die Eischale? Anat. Anz., 41: 381-382.

Pohlman, A. G. 1919. Concerning the causal factor in the hatching of the chick, with particular reference to the musculus complexus. Anat. Rec., 17: 89-104, 2 figs., 8 tables.

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FOOD HABITS OF THE LEOPARD FROG (*RANA PIPIENS SPHENOCEPHALA*) IN A MINNOW HATCHERY

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This paper is based upon an Illinois Junior Academy of Science project.

Due to the abundance of ideal habitat free from predaceous fishes, the leopard frog is unusually abundant in most minnow hatcheries. In view of its abundance it is desirable to know whether or not it feeds on minnows.

Other studies have been made on the food habits of the leopard frog, but not on specimens taken where small fishes were known to be abundant. In a study done by Kilby (1935), out of 443 stomachs containing food, the bulk of the food consisted of insects and spiders. The insects were beetles, lepidopterous larvae, crickets, grasshoppers, and some aquatic insects. Knowlton (1944) examined 97 stomachs and found the following: shorthorned grasshoppers, field crickets, leaf hoppers, false chinch bugs, pea aphid, English grain aphid, click beetles, lepidopterous larvae, houseflies, blowflies, mosquitoes, mosquito eggs, deer flies, and ants. In a study done by Drake (1914) out of 209 stomachs, 60 percent contained insects. Other food items included mollusks, crustaceans, myriapods, and spiders.

Study Area

The hatchery at which the study was done is in the Mississippi River bottoms of Jackson County, Illinois near the town of Gorham. The whole study area covered 6 acres. These 6 acres were divided into 19 ponds ranging from 1/20 to 1 acre and ranging in depth from 2 to 4 feet. On the levees and their shorelines. there was a heavy growth of grass and weeds. There were water plants and algae growing on the surface of some ponds.

Method of Procedure

The 46 specimens for the study were collected by the use of an air gun. The stomach contents were determined after dissection.

During the course of the study a record was kept of the availability of the more noticeable food organisms with special reference to the minnow population of the ponds.

Results

Under the conditions of the study area, the leopard frog fed exclusively on insects (Table 1). The majority of these insects were terrestrial. Some aquatic larvae were

TABLE 1.—Stomach contents of 46 leopard frogs[1].

Food Item	Percent Occurrence
Terrestrial Beetles	43
Unidentified Insect Remains	24
Miscellaneous Insects	17
Crickets	11
Aquatic Insect Larvae	9
Empty	7

[1] Collected April 25 to September 12 in a southern Illinois minnow hatchery.

found indicating that the frogs may feed underwater. Minnows, smaller frogs, tadpoles, and crayfish were available in the study area. None of these items were found in the stomachs.

ACKNOWLEDGMENTS

The author wishes to thank his father, Dr. William M. Lewis, Sr. and mother, Mrs. Sue D. Lewis for assistance in identifying food items and in preparation of this paper. The science project upon which this paper is based was sponsored by Mr. Carol Hampton, Lecturer, University School, Carbondale, Illinois.

LITERATURE CITED

DRAKE, CARL J. 1914. The Food Habits of *Rana pipiens*, Schrebar, Ohio Naturalist, 14: 259-269.

KILBY, JOHN D. 1935. Feeding Habits of *Rana pipiens sphenocephala*, Jour. of Fla. Acad. of Sci., 8(1): 71-104.

KNOWLTON, G. F. 1944. Some Insect Food of *Rana pipiens*, a Utah Resource. Copeia, 2: 119.

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STOMACH CONTENTS OF BULLFROGS (*RANA CATESBEIANA*) TAKEN FROM A MINNOW HATCHERY

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In the southern Illinois region, the bullfrog is one of the most abundant vertebrates in minnow hatcheries. It is therefore desirable to establish its status as a predator on minnows. This was the objective of the present study.

The study was done as a science project for the Illinois Junior Academy of Science.

Several studies have been made of the natural feeding habits of the bullfrog. Among the more exhaustive is that of Korschgen and Moyle (1955), who examined the contents of 455 stomachs from specimens collected from central Missouri farm ponds. The percent volume for the principal food items were as follows: insects, 32; crayfishes, 26; frogs, 11; tadpoles, 10; meadow mice, 3; fishes, 2; snails, 2; toads, 2; miscellaneous invertebrates, 2; and snapping turtles, 1.

Frost (1935) reported that insects comprised the greatest part of the diet of 25 smaller frogs. Ants were eaten in considerable numbers. Spiders and snails formed the largest part of the diet by volume. Upon examining the larger bullfrogs, Frost found crayfishes in 4, frogs in 2 and mice in 2.

Needham (1905) concluded that snails and insects were the main items of the diet. In 16 bullfrogs collected from New York, he found 18 snails, 3 spiders, 3 crustaceans and 2 vertebrates.

A study by Perez (1951) in Puerto Rico showed the following principal food items in terms of percent volume of total stomach content: insects, 19; plant matter, 11; and bullfrogs, 4.

Pope (1947) gives the combined results of five workers who tabulated the contents of about 200 stomachs and more casual information from others. The diet of young frogs was comprised of insects and other small invertebrates, at least half of which were non-aquatic. Larger frogs preyed upon numerous invertebrates and vertebrates such as fishes, frogs, salamanders, young turtles, snakes, moles, mice and birds. Frogs and crayfishes seemed to be the chief food items of larger frogs.

Other more casual observers add to the widely varied list of food items. Baker (1940) gave crayfishes as the chief food item of the bullfrog in eastern Texas. Dickerson (1906) lists fishes, small turtles, young water birds, and frogs as food items forming the greatest part of the diet. Breckenridge (1944) includes insects, fishes, crayfishes, birds, and other frogs as popular food items. Morris (1945) states that the bullfrog is cannibalistic to a marked degree. Other food items listed by Morris are mice, crayfishes, salamanders, snails, small fishes, worms, and various insects, both lar-

val and adult, that are found among the water weeds.

Dyche (1914) examined 30 stomachs from bullfrogs taken from a Kansas fish hatchery. He found 32 fishes in 14 of the 30 stomachs. Other items found included crayfishes, insects, spiders, and snails.

Study Area

The frogs utilized in this study were taken from a minnow hatchery located in the Mississippi River Bottoms of Jackson County, Illinois. The collecting area covered 6 acres. Within this area were 19 ponds ranging in size from 0.05 to 1.0 acre. Throughout the summer and fall, the levees of the ponds were covered with a dense growth of vegetation.

Method

The original plan of sampling called for collecting ten frogs per week. This plan was followed from spring to midsummer. However, after this time, the frogs became so scarce and vegetation cover so dense that it was not possible to obtain the desired number. It was also noted that the larger frogs became relatively more scarce. A total of 123 frogs were utilized in the study.

The specimens were collected primarily during the daylight hours by use of a .22 caliber rifle. They were all collected in the water or at the water's edge. As each frog was collected it was marked as to which pond it was taken from and stomach contents were determined by dissection. The size of frog was measured from the snout to the posterior end of the body. The abundance of various food items in the habitat was noted throughout the course of the study.

Results

Plant matter constituted only a minor portion of stomach contents and was considered to be accidentally ingested with food. For this reason it was not listed with stomach contents (Table 1).

Insects were found to be in 68 percent of the stomachs examined. Terrestrial beetles (32 percent), aquatic beetles (24 percent), and dragon flies (13 percent), were the most numerous food organisms in this group. Dragonflies constituted a large part of the diet in July, August, and September, probably because of availability. Twenty-five other kinds of insects were recognized but were relatively unimportant as food items.

Crayfishes (especially *Orconectes immunis*) found in 30 percent of the stomachs examined constituted the second most prevalent food item. A decrease in the number of crayfishes eaten in late summer was probably due to a poisoning program which reduced the number of crayfishes present in the ponds.

Frogs (especially *Rana pipiens*) were the third most prevalent food item and were found in 24 per cent of the stomachs examined. Although cricket frogs (*Acris gryllus* were known to be abundant in the study area at the time the bullfrogs were being collected they occurred in only 1.6 percent of the stomachs examined. Young Fowler's toads (*Bufo woodhousei*) were also abundant in May and June, but none were found in the stomachs of the bullfrogs examined.

TABLE 1.—Percent Occurrence of Food Items in Stomachs of 123 Bullfrogs Collected From Minnow Hatchery Ponds, Gorham, Illinois.

Food Item	Percent Occurrence		Food Item	Percent Occurrence	
Insects (Total)		68.3	Water Strider	0.8	
Terrestrial Beetles	31.7		Horsefly or Cranefly Larvae	0.8	
Aquatic Beetles	24.4		Cranefly Larvae	0.8	
Dragon Flies	13.0		Terrestrial Bug	0.8	
Unidentified Flies	8.1		Cricket	0.8	
Terrestrial Moth or Butterfly Larvae	6.5		Crayfishes		30.1
Dragon Fly Larvae	5.7		Frogs (Total)		24.3
Unidentified Insect Remains	5.7		Leopard Frogs	10.6	
Aquatic Beetle Larvae	5.7		Unidentified Frogs	8.9	
Damsel Flies	4.1		Cricket Frogs	1.6	
Aquatic Bugs	4.1		Bullfrog Tadpoles	1.6	
Grasshoppers	2.4		Frog Eggs	1.6	
Syrphid Flies	2.4		Fish (Total)		13.8
Aquatic Fly Larvae	1.6		Golden Shiners	8.9	
Honey Bees	1.6		Unidentified Fishes	4.1	
Bumble Bees	1.6		Fathead Minnows	0.8	
Water Boatmen	1.6		Snails		8.4
Leaf Hopper	0.8		Spiders		8.1
Damsel Fly Larvae	0.8		Empty		7.3
Moth	0.8		Millipedes		4.1
Unidentified Aquatic Insect Larvae	0.8		Painted Turtle		0.8
Firefly	0.8		Rabbit Hairs		0.8
Midge	0.8		Mice		0.8
Backswimmer	0.8		Unidentified Animal Remains		0.8
			Unidentified Hairs		0.8

Since the primary objective of this study was to determine the status of the bullfrog as a predator on fishes, the data collected for this study were analyzed with this purpose in mind. Fishes were the fourth most prevalent food item. Minnows (*Notemigonus crysoleucas* and *Pimephales promelas*) were known to be abundant in most ponds on the hatchery but were found in only 14 percent of the stomachs examined. On comparing size of frog with stomach contents, it was found that larger frogs fed more heavily on minnows. They occurred in 25 percent of the stomachs from frogs 6 inches or over, 15 percent in 5-inch to 6-inch frogs, 7 percent in 4-inch to 5-inch frogs, and 9 percent in frogs 3 inches or less in body length.

Conclusions

Under conditions existing in a bottomland minnow hatchery of the southern Illinois region, the bullfrog appears to utilize primarily insects, crayfish, frogs, and minnows as food. Of these principal items minnows are utilized the least. It is questionable if the bullfrog constitutes a very serious predator on minnows under hatchery conditions.

Acknowledgments

The writer is indebted to his father Dr. William M. Lewis and his mother Mrs. Sue D. Lewis for aid in identification of food items and preparation of this report and to Mr. Carol Hampton, Lecturer, University School, Carbondale, Illinois, who sponsored the science project upon which this paper is based.

Literature Cited

Baker, R. H. 1942. The Bullfrog, a Texas Resource. Texas Game and Fish Comm. Bull., 23, pp. 3-7.

Breckenridge, W. J. 1944. Reptiles and Amphibians of Minnesota. Univ. Minn. Press, Minneapolis, Minn., 202 pp.

Dickerson, Mary C. 1907. The Frog Book. Doubleday, Page and Co., New York, 253 pp.

Dyche, L. L. 1914. Ponds, Pond Fish, and Pond Fish Culture. State Dept. Fish and Game, Kan. Bull., 1: 149-158.

Frost, S. W. 1935. The Food of *Rana catesbeiana* Show. Copeia, 1: 15-18.

Korschgen, J., and D. L. Moyle. 1955. Food Habits of the Bullfrog in Central Missouri Farm Ponds. Amer. Mid. Nat., 54(2): 332-341.

Morris, Percy A. 1945. They Hop and Crawl. Jaques Cattell Press, Lancaster, Pa. 253 pp.

Needham, J. G. 1905. The Summer Food of the Bullfrog (*Rana catesbeiana*) Shaw at Saranac Inn. N. Y. State Mus. Bull., 86: 9-15.

Perez, M. E. 1951. The Food of *Rana catesbeiana* Shaw in Puerto Rico. Jour. Agric. Univ. Puerto Rico, 35(4): 136-142.

Pope, C. H. 1947. Amphibians and Reptiles of the Chicago Area. Chicago Nat. His. Mus., 275 pp.

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OBSERVATIONS ON A COLONY OF BIG-EARED BATS, *PLECOTUS RAFINESQUII*[1]

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Colonies of big-eared bats, *Plecotus rafinesquii,* are so uncommonly found that our limited observations of a small colony are worthy of recording. A small colony occupies an unused cistern, now far removed from any buildings, about one mile northeast of Reelfoot Lake, Obion County, western Tennessee. The bats were first discovered in the cistern in May 1950, but they were present "many years" before that, according to local residents. During the months we have visited the cistern—February, March, April, May, and September—from 1 to 64 *Plecotus rafinesquii,* and only this species, have been present.

The cistern is located in slightly rolling country among the bluffs back from Reelfoot Lake. The immediate area has a sparse second growth of trees, most of which are under 30 feet high. To the north there is a thicket of blackberries but no trees. The mouth of the cistern projects 2 feet above ground level and is 30 inches in diameter. It is always open. The cistern is about 25 feet deep and "bells-out" inside (see Fig. 1). The cistern is built of bricks and stone but the inner face is smoothed with cement. Water, always present in the bottom, fluctuates in depth but is always less than 8 inches deep in our exerience.

Plecotus rafinesquii hang in the top-half of the cistern in the warmer parts of the year (May 25, September 2 and 3). In the colder months they hang in the bottom half. On the occasion when 64 bats were present, most of them hung in three clusters, 4½ to 6½ feet above the water (see Fig. 1) with about 20 in each cluster. Two or three individuals were hanging separately higher on the walls. On cold days, these bats are apparently in hibernation, for they are cold to the touch, their ears are rolled down, and the bats are so sluggish that bands could be attached to most individuals before they aroused.

The hibernating chamber must become cold at certain times and must receive considerable light since there is no cover on the cistern. On the night of March 21, 1960, the temperature outside the cistern was as low as 8°F; earlier in the winter the temperature was lower. On April 2, 1961, at 8:30 a.m., the temperature near the bottom of the cistern was 49°F; at ground surface, 51°F. We do not know if the temperature drops below freezing within the cistern but suspect that it must on occasions. Light filters in the top of the cistern, especially on bright days, and it must be considerably lighter here than just inside the entrance of most caves.

Big-eared bats must move in and out of this colony during the winter months. For example, on February 14, 1961, about 50 *Plecotus* were present of which 13 had bands previ-

[1] Aid for this study was furnished in part by N.S.F. grant G 19392.

ously affixed. On April 1, 1961, one and one-half months later, only 3 of the banded bats were present yet it was too cold for them to be active within the cistern. On April 1, the ground surface temperature was about 34° F.; earlier on February 14, it was about 60° F. On the latter date, the bats were active within the cistern and it appeared as if they might be copulating.

Some *Plecotus* use the cistern more than one winter, but new individuals move in with the "resident" bats on succeeding years. On March 21, 1960, 60 bats were banded in the cistern. About 11 months later, on February 14, 1961, of about 50 bats present, only 13 had been banded previously. On April 1, 1961, of 28 bats, 11 had been banded a little over a year before. However, among these 11, only 3 were from the 13 wearing bands observed on February 14. On April 4, 1962, of 3 bats present, one was banded 2 years earlier and one was banded one year earlier. It appears that throughout the cold period of late winter and early spring, there is a movement of bats in and out of this colony.

A colony of *Plecotus rafinesquii* can be greatly reduced or depleted in size and it will successfully rebuild. Early in our observations, most of the colony was removed. On May 25, 1950, only 1 bat was present and it was removed; on September 2, 1950, 16 bats were present and 15 were removed; on May 31, 1951, 28 bats were present and 25 were removed. Within a year's time, 41 of 45 bats were removed and preserved as skins. Nevertheless, on March 21, 1960, 9 years later and the time of our next thorough survey, the largest concentration of bats ever noted, 64 in all, was present.

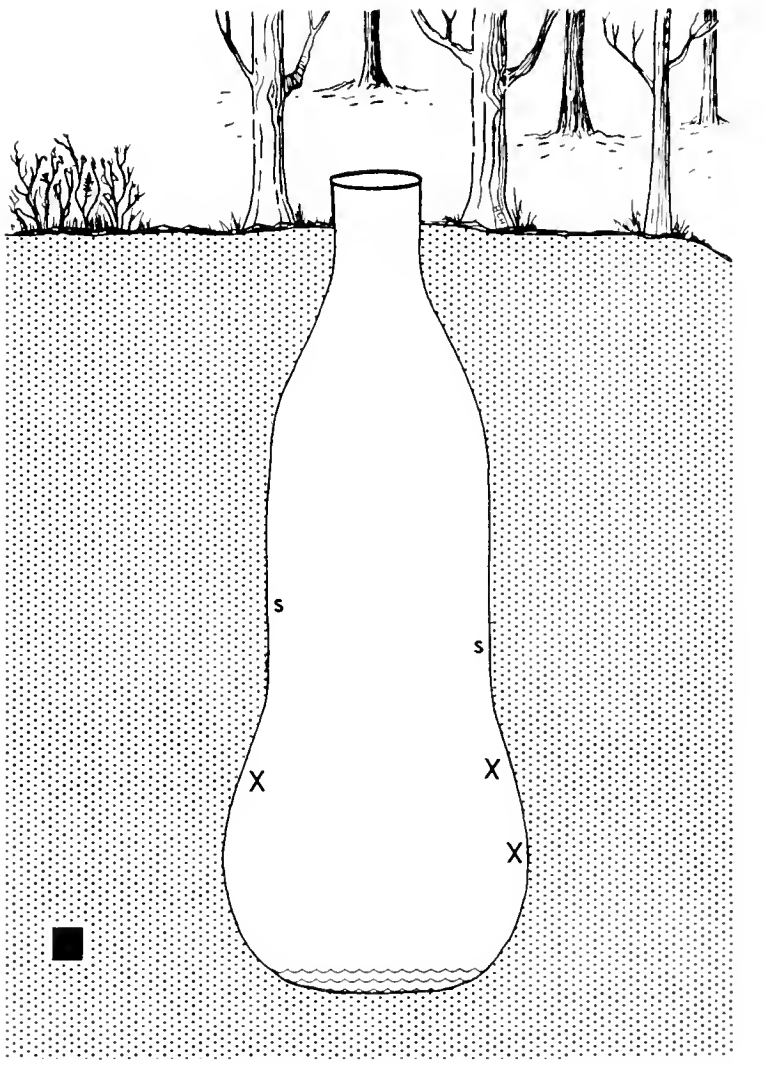

FIG. 1.—Cross section of abandoned cistern which houses *Plecotus rafinesquii*. The position of the 3 large clusters, X, and single individuals, s, of bats as on March 21, 1960, is shown. The black square indicates one square foot. Drawing by H. C. Henrikson.

Nine bats were taken from the cistern to Cincinnati, Ohio, on August 4, 1957, banded, and released. This was 345 miles away from the cistern. None was ever recovered back at the cistern or, so far as we know, anywere else.

Six of the eleven big-eared bats taken in the cistern on September 2 and preserved as skins and skulls appear to be young of the year. However, these young, thought to be about 3 months old, have the epiphyses of the fingers nearly closed and are as large as winter-taken specimens. These 6 differ from adults

primarily in having shorter fur with the hairs on the back lacking the glossy brown tips. An age of 3 months is estimated for these young on the basis of specimens in the collection from Mammoth Cave, Kentucky, one of which appears to be about 2 weeks old, collected June 17, and another taken on July 6 which could be about 5 weeks old. The birth date for both of these was near June 1.

Twenty-eight adults (14 males, 14 females) from the one locality near Reelfoot Lake, only 164 miles southwest of the type locality of *Plecotus rafinesquii rafinesquii,* provide the following averages and extremes, all in millimeters. Measurements of the skull are taken according to Handley (1959:98), with the males listed first. Total length, 97.8 (94-102), 99.6 (93-105); tail length, 49.8 (46-53), 50.3 (47-54); hind foot length, 10.7 (9-12), 11.2 (9.5-12); ear from notch, 33.5 (29-35), 34.1 (27-37); length of forearm, 43.0 (41.8-44.4), 43.3 (41.7-45.0); tragus (as taken by collector), 12.8 (10-16), 13.6 (11-16); greatest length of skull, 16.14 (15.8-16.5), 16.35 (16.1-16.65); zygomatic breadth, 8.80 (8.4-9.1), 8.87 (8.5-9.15); interorbital breadth, 3.57 (3.45-3.7), 3.60 (3.45-3.7); breadth of braincase, 7.85 (7.6-8.8), 7.90 (7.7-8.1); depth of braincase, 6.03 (5.9-6.25), 6.03 (5.85-6.25); maxillary toothrow length, 5.32 (5.25-5.45), 5.35 (5.2-5.5); postpalatal length, 5.98 (5.7-6.1), 6.04 (5.8-6.4); palatal breadth, 6.12 (5.85-6.3), 6.15 (6.0-6.35). All specimens have a well-developed secondary cusp present on the first upper incisor except for one specimen. In this, the incisor is much as in *Plecotus townsendii.*

Summary

Big-eared bats, *Plecotus rafinesquii,* may use as roosting places certain cavities that are well lighted and become cold during the winter. Such is the case for big-eared bats inhabiting an abandoned, unused, uncovered cistern in westernmost Tennessee. Only *Plecotus rafinesquii* occupies this cistern and in numbers varying from 1 to 64 individuals. They are present in winter, spring, and summer, and probably throughout the year. During the winter, bats move in and out of the hibernating chamber, with individuals from different localities taking places of those moving out. The same individuals may be present for parts of two consecutive winters, but not continuously in the winter nor in the summer. When only about 3 months old, big-eared bats are adult-size.

Literature Cited

Handley, C. O., Jr. 1959. A revision of American bats of the genera Euderma and Plecotus. Proc. U. S. Nat. Mus., 110:95-246.

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A SECOND PORCUPINE RECORD FOR ILLINOIS

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Approximately 3,200 bones and over 33,000 freshwater mussel valves (37 species) were identified from the faunal samples recovered at three Archaic Indian sites situated along the Wabash River in east-central Illinois. The field work at these sites (Riverton, Swan Island, Robeson Hills) took place during April, May, June and October, 1961, and was supervised by Mr. Howard D. Winters of the Illinois State Museum. The sites were spaced nearly equal distance (10 miles) from one another: Riverton, two miles northeast of Palestine, Crawford County, and Swan Island, located at the present Crawford-Lawrence county line were situated on the river flood plain, while the Robeson Hills village (two miles north of Vincennes, Indiana, Lawrence County, Illinois) occurred on the river bluff (isolated aggraded upland). Artifact assemblages, the faunal complex and radio-carbon dates suggest that the sites were occupied by the same group at different seasons or by contemporaneous groups.

Fish remains were more abundant at the Riverton and Swan Island sites, those of catfishes, bowfin and freshwater drum being the most numerous. Turtles had been taken in considerable numbers (six species represented). Although a minimum of 17 species of birds were identified, only the turkey had been utilized extensively. Of all vertebrate groups, mammals (22 species) were the most important source of food to these peoples, the white-tailed deer constituting the basic meat staple in their diet. Numerous bones of raccoon, gray squirrel, beaver, cottontail, muskrat and other small mammals from these sites were indicative of former populations and of their extensive use by these Archaic groups.

Recovery of one skull and four mandible sections of the porcupine (*Erethizon dorsatum*) from the Rivton Site constitutes a noteworthy zoological record for the area. There are no historic accounts which definitely establish the porcupine as a former resident of Illinois and, previous to the recovery of the Riverton Site material, no remains have been found in any of the other numerous archaeological sites investigated thus far. The first record to indicate a former population of porcupine in Illinois consisted of several cranial bones and jaws recovered from a natural cave in Monroe County (Parmalee, Bieri and Mohrman 1961). This isolated find probably represents an early southern range extension of this rodent along the Mississippi River bluffs.

The Riverton Site material consisted of portions of four lower mandibles (three right jaws, consequently at least three individuals represented) and the right maxilla containing the premolar and molars 1 and 2. Two jaws contained the premolar and molars 1 and 2; one con-

tained all three molars, and the fourth jaw retained only molars 2 and 3. Fragments of an incisor and the proximal end of a radius from this site may also be referable to *E. dorsatum*. Two jaws found in the 36-42 inch level were dated, based on C 14 tests of charcoal from the levels, at 3,100 ± 200 years B.P.; the date from the 60-66 inch level, in which a third jaw was recovered, was 3,200 ± 200 years B.P.

The question arises as to whether the Indians obtained porcupines on the Illinois or Indiana side of the Wabash River. Lyon (1936) lists the published records with the dates of observation and the specimens in collection of the porcupine in Indiana; three were from counties (Vigo, Knox, Posey) bordering the Wabash River. There was no record of *E. dorsatum* from Sullivan County, Indiana, the county immediately east of Crawford County, Illinois, and the Riverton Site. This rodent was recorded from Vigo and Knox counties which border Sullivan County on the north and south, respectively, and it could have been quite possible for the Indians to have easily covered these short distances (minimum of about 15 miles) while hunting. However, the Archaic inhabitants of the Swan Island and Robeson Hills sites were closer to the porcupine's known range in Indiana (Knox County, directly across the river), yet no remains of it were recovered at either site.

Rising over 150 feet above the Wabash River flood plain, Merom Bluff (about 1½ miles northeast of the Riverton Site, Sullivan County, Indiana) is a 2½ mile long section of wooded, sandstone bluff that could have served as suitable habitat for the porcupine. Approximately 2½ miles south of the Riverton Site (Crawford County, Illinois), and paralleling the river for about 1½ miles, is another wooded bluff (over 120 feet above the flood plain) that may also have been inhabited by this animal. Future archaeological excavations throughout the lower Wabash River Valley may establish conclusively the presence of a prehistoric population of porcupine on the Illinois side of the river. However, these remains of *E. dorsatum* from the Riverton Site are indicative of its former occurrence locally in the Crawford County, Illinois—Sullivan County (?), Indiana area.

Literature Cited

Lyon, Marcus W., Jr. 1936. Mammals of Indiana. Amer. Mid. Nat., 17(1): 384 pp.

Parmalee, Paul W., R. A. Bieri and R. K. Mohrman. 1961. Mammal remains from an Illinois cave. Jour. Mamm., 42(1): 119 pp.

GEOGRAPHIC AND HOST DISTRIBUTION OF BLOOD PARASITES IN COLUMBORID BIRDS

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Synopsis

Available data on geographic distribution and incidence of blood parasites in different host species of columborid birds in the wild are assembled from 174 reports in the literature, analyzed, and information on life cycles and pathogenesis is given. The most common genus is *Haemoproteus*, of which two species occur in naturally affected birds. The more common species is *H. columbae*, the gametocytes of which extend along one side of the host erythrocyte and curve around its ends. It has been found in 14 host species in 24 countries. *H. sacharovi* has gametocytes which completely fill the host cell when mature. It has been found in 3 host species in the United States and Italy.

Trypanosoma avium has been reported from 7 host species in 6 countries.

Three species of *Plasmodium* have been reported. *P. relictum* is by far the most common; it has been found in 3 host species in 5 countries. *P. elongatum* has been found in 1 host species (*Zenaidura macroura*) in the United States. *P. hexamerium* has also been found in *Z. macroura* in the United States and possibly also in *Columbigallina talpacoti* in Colombia.

Leucocytozoon marchouxi, which has rounded gametocytes, has been reported from 13 host species in 15 countries. A species of *Leucocytozoon* with elongate gametocytes has been seen once in Uganda. *Leucocytozoon* has not been reported from South or Central America despite the fact that a number of surveys have been made there.

Toxoplasma gondii has been identified by mouse inoculation or dye test or both in 8% of 176 domestic pigeons in 4 surveys in different parts of the United States. What may have been *Toxoplasma*, *Lankesterella* or possibly some other genus has been found in 3 host species in 4 countries. The possible role of the domestic pigeon as a reservoir of *Toxoplasma gondii* is mentioned.

The distribution of blood protozoa in columborid birds is poorly known. *Haemoproteus* has been reported from only 20% of the known 61 genera and 8% of the known 320 species of these birds, *Plasmodium* has been found in 11% of the genera and 3% of the species, *Leucocytozoon* in 10% of the genera and 4% of the species, *Trypanosoma* in 8% of the genera and 2% of the species, and *Toxoplasma* or a similar form in 3% of the genera and 1% of the species. The parasite species has been identified in only 58% of 138 reports of *Haemoproteus*, 62% of 26 reports of *Plasmodium*, 35% of 26 reports of *Leucocytozoon*, 60% of 10 reports of *Trypanosoma*, and 77% of 13 reports of *Toxoplasma* and similar forms. In 43% of the total of 213 records, the species name of the parasite was not given. In only 41 (24%)

of the 173 papers were 10 or more birds of a single species examined, and in only 12 (7%) of them were 100 or more birds examined.

Introduction

Our present information on the blood parasites of birds of the order Columborida is, with a few exceptions, both scattered and scanty. It has been tabulated by Levine and Kantor (1959), and the analyses in the present paper are based primarily on the raw data in their tables. Additional information from other papers has been included as indicated. The only references given at the end of this paper are to the papers specifically discussed in the text; all others and the sources of all data can be found in Levine and Kantor (1959). Records of blood parasites from birds in zoos have not been tabulated, since they do not necessarily mirror the true situation in the wild. The surveys discussed in the text are for the most part only those in which 100 or more birds were examined. The results of surveys in which fewer birds were examined are given in the tables.

Trypanosoma. Trypanosomes were first found in columborid birds by Novy and MacNeal (1905a, b) in mourning doves (*Zenaidura macroura*) in Michigan; they thought that they were probably *Trypanosoma avium*. De Mello and Bras de Sa (1916) found a trypanosome which they named *Trypanosoma hannai* in domestic pigeons (*Columba livia*) in Portuguese India, and Sergent (1941a, b) found a trypanosome which he named *T. oenae* in *Oena capensis* in the Nigerian Sahara. Wood and Herman (1943) and Coatney and West (1938) used the name *T. avium* for the trypanosomes which they found in *Zenaida asiatica mearnsi* in Arizona and in *Zenaidura* sp. in Nebraska, respectively.

Trypanosoma avium Danilewsky, 1885 was first described from owls (scientific name not given) and roller-birds (*Coracias garrulus*) in Europe, and has since been reported from a wide variety of birds. Various other names have been given to trypanosomes in other birds, largely on the basis of their presence in a different host from those previously reported. The validity of most of these names, including *T. hannai* and *T. oenae*, is highly questionable.

Bennett (1961) studied the morphology of trypanosomes from 25 species of birds belonging to 11 families (but not including any columborid birds), and concluded that they were all the same species except for a trypanosome which he found once in a chipping sparrow (*Spizella passerina*); he considered the chipping sparrow form to be *Trypanosoma paddae* Laveran and Mesnil, 1904 and all the others to be *T. avium*.

Cross transmission studies on avian trypanosomes have been carried out by Baker (1956a, b) and Bennett (1961). The former transmitted *T. avium* from the rook (*Corvus frugilegus*) and jackdaw (*C. monedula*) to canaries, but failed to transmit it to a single 3-day-old chick. Bennett (1961) transmitted strains of *T. avium* by means of simuliids or *Aedes aegypti* from 9 species of birds belonging to 4 orders into 15 species of birds belonging to 5 orders. Many of these trans-

missions were from birds of one order to those of another. Bennett made no attempt to infect every receptor host species with a strain from every donor host species, but used enough combinations to show that it would have been possible. Among them, he infected the pigeon with strains from the blue jay and saw-whet owl.

On the basis of the above morphologic and cross-transmission studies, it is safe to conclude that *Trypanosoma avium* occurs widely in many different orders of birds and that, unless they are proven to be different, all avian trypanosomes should be referred to this species.

Blood-sucking arthropods such as blackflies, mosquitoes and hippoboscid flies are the vectors of avian trypanosomes. Baker (1956a, b) worked out the life cycle of *T. avium* from rooks and jackdaws. He found that in England the hippoboscid fly, *Ornithomyia avicularia,* acts as the vector and that birds become infected when they eat insects which have become infected by sucking blood. According to Baker, there is no multiplication in the avian host, the trypanosomes simply becoming larger; multiplication takes place only in the arthropod host.

Bennett and Fallis (1960) compared the incidence and level of parasitemia of *Trypanosoma* with the occurrence and feeding habits of

TABLE 1.—Known Geographic Distribution and Prevalence of *Trypanosoma* in Columborid Birds.

Country	Bird Species	Prevalence (%)		
		Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
EUROPE				
Germany	*Columba palumbus*		24	24
ASIA				
Portuguese India	*Columba livia*	+		
West Java	*Streptopelia chinensis*		8	8
AFRICA				
Nigerian Sahara	*Oena capensis*	+		
Gambia	*Streptopelia vinacea*	+		
NORTH AMERICA				
Arizona	*Zenaida asiatica mearnsi*		8	
U. S. A.	*Zenaidura macroura carolinensis*		0.5	0.5
Michigan	*Zenaidura macroura carolinensis*	+		
Nebraska	*Zenaidura macroura carolinensis*	+		

TABLE 2.—Known Geographic Distribution and Prevalence of *Plasmodium* in Columborid Birds.

Country	Bird Species	*Plasmodium* Species	Prevalence (%)		
			Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
EUROPE					
Germany	*Columba palumbus*	*relictum*		48	48
Czechoslovakia	*Columba palumbus*	sp.	+		
ASIA					
Japan	*Streptopelia orientalis*	sp.		13	13
AFRICA					
Egypt	*Columba livia*	*relictum*	+		
French Congo	*Columba livia*	*relictum*	+		
Algeria	*Streptopelia turtur*	sp.	+		
Belgian Congo	*Treron calva*	sp.	+		
NORTH AMERICA					
U. S. A.	*Columba livia*	*relictum*	+		
California	*Columba livia*	*relictum*		5	
Iowa	*Columba livia*	*relictum*		20	
Arizona	*Zenaida asiatica mearnsi*	sp.		83	
U. S. A.	*Zenaidura macroura*	*elongatum*		1	1
U. S. A.	*Zenaidura macroura*	*relictum*	+		
U. S. A.	*Zenaidura macroura*	sp.		0.5	0.5
Illinois	*Zenaidura macroura*	*hexamerium*		1	1
Nebraska	*Zenaidura macroura*	*relictum*		9	
D. C. & vicinity	*Zenaidura macroura*	sp.	+		
California	*Zenaidura macroura*	*relictum*		1	1
Mexico	*Leptotila verreauxi*	sp.	+		
SOUTH AMERICA					
Colombia	*Columba cayennensus*	sp.		5	
Uruguay	*Columba livia*	*relictum*	+		
Colombia	*Columbigallina talpacoti*	*hexamerium* (?)	+		

various ornithophilic flies in Algonquin Park, Canada, and concluded that the vectors are probaly simuliids. Their study did not include any columborid birds. Bennett (1961) found that several species of simuliid flies and also *Aedes aegypti* could act as vectors of *T. avium*. Leptomonad, crithidial and metacyclic trypanosome forms developed in the midgut and hindgut of the simuliids, and infection took place when trypanosomes which had been passed in the feces entered the host thru breaks in the skin produced by the feeding flies. Bennett's experiments indicated that birds could be infected by eating flies only if the insects were crushed enough to release flagellates from the hindgut into the birds' mouths.

Nothing is known of the pathogenicity of avian trypanosomes. They are presumably non-pathogenic.

The known geographic distribution and prevalence of *T. avium* in columborid birds are shown in Table I. Only three surveys have been reported in which 100 or more birds were examined, and only four in which more than 10 birds were examined. Bőing (1925) found *Trypanosoma* sp. in 24% of 128 *Columba palumbus* in Germany; Kraneveld and Mansjoer (1954) reported it in 8% of 2100 *Streptopelia chinensis tigrina* in West Java; Huff (1939) reported it in 0.5% of 188 *Zenaidura macroura carolinensis* in the United States; and Wood and Herman (1943) reported *Trypanosoma avium* in 8% of 12 *Zenaida asiatica mearnsi* in Arizona. (As the result of a printing error, the host species was listed by Levine and Kantor (1959) as *Zenaidura macroura*; actually, Wood and Herman found no trypanosomes in the 27 *Z. macroura* which they examined.)

To these surveys should be added several in which no trypanosomes were found, such as that of Hanson *et al.* (1957) in mourning doves in Illinois; these can be identified by comparison with the data on *Haemoproteus* (Table 3).

Plasmodium. Three species of *Plasmodium* have been reported from naturally infected columborid birds in the wild. *P. relictum* is by far the most common. Bőing (1925) found it in 48% of 128 *Columba palumbus* in Germany; Herman *et al.* (1954) found it in 5% of 43 *Columba livia* and 1% of 383 *Zenaidura macroura* in Kern County, California; Mathey (1955) found it in 3 *C. livia* in the Sacramento area of California; Becker, Hollander and Pattillo (1956) found it in 20% of 15 *C. livia* in Iowa; and Coatney (1938) found it in 9% of 11 *Zenaidura macroura* in Nebraska. In addition, it has been reported from *Columba livia* in Egypt, the French Congo and Uruguay.

Plasmodium elongatum was found in 1% of 188 *Zenaidura macroura carolinensis* from the United States by Huff (1939), and *P. hexamerium* was found in 1% of 134 *Z. macroura carolinensis* in Illinois by Huff (1935). Renjifo-Salcedo, Sanmartin and Zulueta (1952) found a *Plasmodium* which they thought might be *P. hexamerium* in 17% of 6 *Columbigallina talpacoti* in Colombia.

In addition to the above 3 species, mention should be made of the form which Carini (1912) described under the name *Plasmodium columbae* from a pigeon which had died of toxoplas-

mosis following experimental infection with a canine strain of *Toxoplasma gondii*. Its gametocytes were halter-shaped and resembled those of *Haemoproteus columbae;* in addition to these, Carini found many round, oval or halter-shaped parasites with slender cytoplasmic extensions or pseudopods. Carini was not sure that he was actually dealing with a *Plasmodium*, since he saw no schizonts. In the absence of confirmation in the ensuing 49 years, *Plasmodium columbae* cannot be accepted as a valid species or even as a *Plasmodium*. I consider the name a *nomen nudum*.

In addition to the named species, *Plasmodium* sp. has been found in *Columba palumbus* in Czechoslovakia, in 13% of 111 *Streptopelia orientalis* in Japan by Ogawa (1912). in *Streptopelia turtur* in Algeria, in *Treron calva* in the Belgian Congo, in *Zenaida asiatica mearnsi* in Arizona, in 0.5% of 188 *Zenaidura macroura carolinensis* in the U. S. by Huff (1939), in *Leptotila vereauxi* in Mexico, and in *Columba cayennensis* in Colombia.

Wolfson (1937, 1940) infected domestic pigeons (*Columba livia*) experimentally with *P. cathemerium*, and Huff *et al.* (1950) and Huff and Marchbank (1955) infected domestic pigeons experimentally with *P. fallax*.

The known geographic distribution and prevalence of *Plasmodium* in columborid birds are shown in Table 2. The results of surveys in which 100 or more birds were examined have been given above. There have been only 5; in Germany, Japan, California, Illinois and the U. S. in general. To these should be added several surveys in which no *Plasmodium* was found, such as that of Hanson *et al.* (1957) in mourning doves in Illinois; these can be identified by comparison with the data on *Haemoproteus* (Table 3).

In sum, *Plasmodium relictum* has been found in the wild in *Columba livia, C. palumbus* and *Zenaidura macroura*. It has also been reported in zoos in *Columba argentia, Ducula concinna, Leptotila crumeniferus, Megaloprepia magnifica Scardafella squammata, Tympanistria bicolor*, and *T. tympanistria*. *Plasmodium elongatum* has been reported only from the mourning dove, *Zenaidura macroura*. *Plasmodium hexamerium* has been reported with certainty from *Z. macroura* and questionably from *Columbigallina talpacoti*. Unidentified species of *Plasmodium* have been reported in *Columba palumbus, C. cayennensis, Leptotila verreauxi, Streptopelia orientalis, S. turtur, Zenaida asiatica mearnsi* and *Zenaidura macroura* in the wild, and in *Columba squamosa*, and *Tympanistria tympanistria* in zoos. In all, *Plasmodium* has been found in a total of 10 identified species of columborid birds in the wild, and in 9 others in zoos.

Haemoproteus. This is by far the most common genus of blood protozoon in columborid birds. Two species occur in naturally infected birds in the wild. The more common one is *H. columbae*, which has so-called halter-shaped gametocytes which extend along one side of the host cell nucleus and curve around its ends. This species was originally described by Celli and Sanfelice (1891a, b) from the domestic pigeon and has

TABLE 3.—Known Geographic Distribution and Prevalence of *Haemoproteus** in Columborid Birds.

Country	Bird Species	Prevalence (%)		
		Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
EUROPE				
Greece	*Columba livia*		18	
Italy	*Columba livia*		83	
Spain	*Columba livia*	+		
Italy	*Columba oenas*	+		
Germany	*Columba palumbus*		20	20
England	*Columba palumbus*	+		
Greece	*Streptopelia decaocto*		23	
Italy	*Streptopelia turtur*		3	
Spain	*Streptopelia turtur*		73	
Germany	*Streptopelia turtur*	+		
ASIA				
Lebanon	*Columba livia*	+		
"Plains," India	*Columba livia*		100	
Delhi, India	*Columba livia*		22	22
Portuguese India	*Columba livia*	+		
Manila, Philippines	*Columba livia*		81	
Wellesley Province India	*Columba* sp.		100	
Palestine	*Columba* sp.	+		
Philippines	*Columba* sp.	+		
Mukteswar, India	*Sphenurus sphenurus*	+		
Formosa	*Streptopelia chinensis*	+		
Tonkin, Vietnam	*Streptopelia tranquebarica*	+		
India	*Streptopelia turtur*	+		
AFRICA				
French Sudan	*Columba guinea*	+		
Algeria	*Columba livia*	+		
Egypt	*Columba livia*	+		
French Morocco	*Columba livia*		45	
French Congo	*Columba livia*	+		
Belgian Congo	*Columba livia*	+		
Portuguese Guinea	*Columba livia*	+		
Un. S. Africa	*Columba livia*	+		
Ethiopia	*Oena capensis*	+		
Un. S. Africa	*Oena capensis*	+		
Mozambique	*Plectopterus gambiensis*	+		
Un. S. Africa	*Streptopelia capicola*	+		
Ethiopia	*Streptopelia decipiens*	+		
Belgian Congo	*Streptopelia semitorquata*	+		
Liberia	*Streptopelia semitorquata*	+		
French Sudan	*Streptopelia senegalensis*	+		
Gambia	*Streptopelia senegalensis*	+		
Algeria	*Streptopelia turtur*	+		

TABLE 3.—Continued

Country	Bird Species	Prevalence (%)		
		Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
French Morocco	*Streptopelia turtur*		40	
French Sudan	*Streptopelia vinacea*	+		
Gambia	*Streptopelia vinacea*	+		
Belgian Congo	*Treron calva*	+		
Gambia	*Treron calva*	+		
NORTH AMERICA				
Ariz. & Calif.	*Columba fasiata*	+		
Colorado	*Columba fasciata*		80	
California	*Columba livia*	+		
D.C., Md., Va.	*Columba livia*	+		
Florida	*Columba livia*	+		
Hawaii	*Columba livia*	+		
Iowa	*Columba livia*	+		
Iowa	*Columba livia*		15**	
Nebraska	*Columba livia*		22**	
Pennyslvania	*Columba livia*	+		
South Carolina	*Columba livia*	+		
U.S.A.	*Columba livia*		100	
U.S.A.	*Columba livia*	+**		
Mexico	*Columba livia*	+		
Arizona	*Zenaida asiatica*		33	
Mexico	*Zenaida asiatica*	+		
Ariz. & Calif.	*Zenaidura macroura*		93	
Ariz. & Calif.	*Zenaidura macroura*		41**	
Northern Calif.	*Zenaidura macroura*	+		
Northern Calif.	*Zenaidura macroura*	+**		
Southern Calif.	*Zenaidura macroura*	+		
D. C. & vicinity	*Zenaidura macroura*	+**		
Georgia	*Zenaidura macroura*		25	
Georgia	*Zenaidura macroura*	+		
Illinois	*Zenaidura macroura*	+		
Illinois	*Zenaidura macroura*		25-43	25-43
Illinois	*Zenaidura macroura*	+**		
Illinois	*Zenaidura macroura*		43-58**	43-58**
Massachusetts	*Zenaidura macroura*		7**	
Massachusetts	*Zenaidura macroura*		8	
Michigan	*Zenaidura macroura*	+		
Michigan	*Zenaidura macroura*	+**		
Nebraska	*Zenaidura macroura*	+		
Nebraska	*Zenaidura macroura*		20	
Nebraska	*Zenaidura macroura*	+**		
Nebraska	*Zenaidura macroura*		67**	
Texas	*Zenaidura macroura*		56	56
Texas	*Zenaidura macroura*		27**	27**
Texas	*Zenaidura macroura*		74	74
U.S.A. (mostly Illinois)	*Zenaidura macroura*		47	47
U.S.A. (mostly Illinois)	*Zenaidura macroura*		56**	56**

TABLE 3.—Concluded

Country	Bird Species	Prevalence (%)		
		Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
SOUTH AND CEN	TRAL AMERICA			
Colombia	*Columba cayennensis*	+		
Colombia	*Columba cayennensis*		71	
Brazil	*Columba livia*	+		
Brazil	*Columba livia*		58	58
Brazil	*Columba livia*		15	
French Guiana	*Columba livia*	+		
Uruguay	*Columba livia*	+		
Argentina	*Columba picazuro*	+		
Brazil	*Columba picazuro*	+		
Brazil	*Columba rufina*	+		
Brazil	*Columba rufina*		92	
French Guiana	*Columba rufina*	+		
Brazil	*Columba* sp.	+		
Brazil	*Columbigallina talpacoti*	+		
Colombia	*Columbigallina talpacoti*	+		
Venezuela	*Columbigallina talpacoti*	+		
Argentina	*Columbigallina picui*		20	20
Brazil	*Columbigallina picui*	+		
Brazil	*Leptoptila* sp.	+		
Brazil	*Scardafella squammata*	+		
El Salvador	*Zenaida asiatica*	+		
Argentina	*Zenaidura auriculata*	+		
Colombia	*Zenaidura auriculata*	+		
AUSTRALIA	*Ptilinopus superbus*	+		

* *H. columbae* unless otherwise indicated.
** *H. sacharovi.*

since been found in many other columborid birds.

Separate specific names have been given to morphologically indistinguishable forms in some hosts: *H. maccallumi* by Novy and MacNeal (1905a) to the form in *Zenaidura macroura*, *H. melopeliae* by Laveran and Petit (1909) to the form in *Zenaida asiatica*, *H. turtur* by Covaleda Ortega and Gallego Berenguer (1950) to the form in *Streptopelia turtur*, and *H. vilhenai* by Santos Dias (1953) to the form in *Plectopterus gambiensis*. Huff (1932) transmitted *H. maccallumi* from the mourning dove to the domestic pigeon, but Coatney (1953) was unable to transmit *H. columbae* from the pigeon to the mourning dove. Both used the hippoboscid fly, *Pseudolynchia canariensis*, as the vector. There may be strain differences between the different

hosts, but until greater differences than these are brought out, it is probably best to use the name *H. columbae* for all species with halter-shaped gametocytes from columborid birds.

Another name, *H. danilewskyi,* was used by some earlier authors for *H. columbae* in columborid birds. This name was originally given by Kruse (1890) to the species in the crow, *Corvus cornix,* and should not be used for parasites of birds of other orders in the absence of proof that they are the same.

One reservation should be kept in mind regarding reports of halter-shaped *Haemoproteus* from birds. This is that in some cases these protozoa may not be *Haemoproteus* at all but a *Plasmodium* species with halter-shaped or elongate gametocytes, such as *P. fallax* or *P. circumflexum,* which does not have schizonts in the blood at the time of examination.

Haemoproteus columbae was found by Giovannoni (1946) in 58% of 159 *C. livia* in southern Curitiba, Brazil; by Singh, Nair and David (1951) in 22% of 214 *C. livia* in Delhi, India; by Huff (1939) in 47% of 188 *Z. macroura* in the United States (mostly in Illinois); by Couch (1952) in 56% of 213 *Z. macroura* in Texas; and by Hanson *et al.* (1957) in 30% of 392 immature *Z. macroura* and in 43% of 72 adult *Z. macroura* in Illinois.

In addition to the above studies in which at least 100 birds of each species were examined, *H. columbae* has been found by various workers in *Columba fasciata* in Arizona and California, in *Columba guinea* in the French Sudan, in *Columba livia* in various parts of the world, in *Columba oenas* in Italy, in *Columba rufina* in Brazil, in *Columbigallina talpacoti* in Venezuela, in *Plectopterus gambiensis* in Mozambique, in *Streptopelia senegalensis* and *S. vinacea* in the French Sudan, in *S. turtur* in French Morocco, in *Zenaida asiatica* in Arizona and El Salvador, in *Zenaidura macroura* on Cape Cod and in Arizona, California and Nebraska, and in *Ptilinopus iozonus* and *Turtur brehmeri* in zoos.

The second species, *Haemoproteus sacharovi,* was first described by Novy and MacNeal (1904a, b) in the mourning dove, *Zenaidura macroura,* in Michigan. Its gametocytes differ from those of most species of *Haemoproteus* in that when mature they completely fill the host erythrocyte, enlarging and distorting it, and often pushing the host cell nucleus to the edge of the cell.

H. sacharovi has been found in both mourning doves and domestic pigeons. It was found by Huff (1939) in 56% of 188 *Z. macroura,* mostly from Illinois; by Couch (1952) in 27% of 213 *Z. macroura* in Texas; and by Hanson *et al.* (1957) in 58% of 392 immature and 43% of 72 mature *Z. macroura* in Illinois.

In addition to the above studies in which at least 100 birds of each species were examined, *H. sacharovi* has been found by various workers in *Columba livia* in Iowa and Nebraska and in *Zenaidura macroura* on Cape Cod and in Arizona, California and Nebraska.

What was almost certainly the same species was described by Franchini (1924) in 3% of 36 *Strepto-*

pelia turtur in Italy. He called his form *Leucocytozoon* sp., but his description and figures fit *H. sacharovi* better than they do *Leucocytozoon.*

The above findings refer to studies in which the species of *Haemoproteus* was named. In addition, *Haemoproteus* sp. has been reported without further identification in *Columba cayennensis* in Colombia, *C. picazuro* and *Columbina picui* in Argentina and Brazil, *Oena capensis* in South Africa and Ethiopia, *Ptilinopus superbus* in Australia, *Scardafella squammata* in Brazil, *Sphenurus sphenurus* in India, *Streptopelia capicola* in South Africa, *S. chinensis* in Formosa, *S. decaocto* in Greece, *S. decipiens* in Ethiopia, *S. semitorquata* in the Belgian Congo and Liberia, *S. tranquebarica* in Tonkin, *Treron calva* in the Belgian Congo and Gambia, *Zenaidura auriculata* in Argentina and Colombia, and in *Capoenas nicobarica, Columba argentina, Columbigallina passerina, Geophaps smithii, Leptoptila crumeniferus, Megaloprepia magnifica, Ptilinopus melanospila, P. periatus, P. wallacei, Treron curvirostra, T. delalandi, Turacoena manadensis* and *Tympanistria tympanistria* in zoos.

The known geographic distribution and prevalence of *Haemoproteus* in columborid birds are shown in Table 3. The results of surveys in which 100 or more birds were examined have been given above. There have been only 8—of *Columba livia* in Hawaii, Brazil and Delhi, India, of *C. palumbus* in Germany, of *Columbina picui* in Argentina, and of *Zenaidura macroura* in Illinois, Illinois and other states, and Texas.

There have been 32 surveys in which 10 or more birds were examined. They involved 11 species of columborid birds in 11 countries, including *Columba cayennensis* in Colombia, *C. fasciata* in Colorado, *C. livia* in the United States (Florida, Hawaii, Iowa, Nebraska), Brazil, Italy, Greece, India, French Morocco and the Philippines, *C. oenas* in Italy, *C. palumbus* in Germany and French Morocco, *C. rufina* in Brazil, *Columbina picui* in Argentina, *Streptopelia decaocto* in Greece, *S. turtur* in Italy, Spain and French Morocco, *Zenaida asiatica* in Arizona, and *Zenaidura macroura* in the United States (Arizona, California, Georgia, Illinois, and other states, Massachusetts, Nebraska, Texas).

The only study of the relation of age to prevalence of *Haemoproteus* was that of Hanson *et al.* (1957) in *Zenaidura macroura.* They found *H. columbae* in 30% of 392 immature and 43% of 72 adult birds in Illinois. The incidence of this species in the immature birds increased steadily with age, from 7 to 8% in very young birds to 70% in older ones. The latter rate was higher than that in the adults.

H. sacharovi was present in 58% of the immature and 43% of the adult birds. Its incidence in the immature birds did not increase nearly so sharply with age as did that of *H. columbae.* It was present in 31% of the very young doves, and its incidence fluctuated between 52% and 69% in older immature birds.

Hanson *et al.* (1957) also studied the incidence of *Haemoproteus* in different years from 1948 thru 1954 and in different parts of Illinois. It varied markedly in both categories.

TABLE 4.—Known Geographic Distribution and Prevalence of *Leucocytozoon** in Columboríd Birds.

Country	Bird Species	Prevalence (%)		
		Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
EUROPE				
Germany	*Columba palumbus*		30	30
England	*Columba palumbus*	+		
Corsica	*Streptopelia turtur*	+		
Italy	*Streptopelia turtur*		3	
Spain	*Streptopelia turtur*		100	
ASIA				
Mukteswar, India	*Sphenurus sphenurus*	+		
Japan	*Streptopelia orientalis*		5	5
Tonkin, Vietnam	*Streptopelia tranquebarica*	+		
AFRICA				
Pretoria, Un. S. Africa	*Columba livia*		82	
French Morocco	*Columba palumbus*	+		
Transvaal, Un. S. Africa	*Oena capensis*	+		
Pietermaritzburg, Un. S. Africa	*Streptopelia capicola*	+		
Uganda	*Streptopelia semitorquata*	+**		
Upper Senegal and Nigeria	*Streptopelia senegalensis*	+		
French Morocco	*Streptopelia turtur*		12	
NORTH AMERICA				
Ariz. & Calif.	*Columba fasciata*	+		
Colorado	*Columba fasciata*		18	
California	*Streptopelia chinensis*		4	
Ariz. & Calif.	*Zenaidura macroura*		15	
D. C. & vicinity	*Zenaidura macroura*	+		
Georgia	*Zenaidura macroura*	+		
Illinois	*Zenaidura macroura*		1.2***	1.2***
Illinois	*Zenaidura macroura*		6.5****	
OTHER				
Mauritius	*Geopelia striata*	+		

* *Leucocytozoon marchouxi* unless otherwise indicated.
** *Leucocytozoon* sp. with elongate gametocytes.
*** Adults.
**** Immature birds.

That of *H. sacharovi* in the immature birds varied from 45% in 1948 to 78% in 1954; in the adults it ranged from 20% in 1953 to 75% in 1951, but these latter figures are based on insufficiently large samples. The incidence of *H. columbae* in the immature birds ranged from 6% in 1950 and 1954 to 43% in 1952; in the adults it ranged from 30% in 1949 and 1950 to 75% in 1952, but this last figure is based on too small a sample. The incidence of *H. sacharovi* in immature birds ranged from 41% in east central in Illinois (Champaign County) to 78% in west central Illinois (Hancock County in 1954); in the adults it ranged from 34% in northeast Illinois (Cook County) to 56% in west central Illinois (Hancock County in 1952-53; no adults were studied from this county in 1954). The incidence of *H. columbae* in immature birds ranged from 6% in west central Illinois (Hancock County in 1954) to 42%, also in west central Illinois (Hancock County in 1952-53); in the adults it ranged from 28% in northeast Illinois (Cook County) to 78% in west central Illinois (Hancock County in 1952-53).

There is no consistent pattern here in the relation of incidence either to year or to location within the state. One can conclude, however, that the results of any survey made at any particular time and place do not necessarily hold true for the same place in a different year or even for a different time in the same year, nor do they necessarily hold true for a different place not too far away during the same time of the same year.

The life cycle of *Haemoproteus columbae* has been studied by Aragão (1908), Adie (1915, 1924) and Huff (1942) among others. The only proven vector is the hippoboscid fly, *Pseudolynchia canariensis* (syns., *Lynchia maura, L. lividicolor, L. capensis*). In addition, Aragão (1916) stated that *Microlynchia pusilla* is a vector in South America, but gave no experimental evidence. Baker (1957) found that *H. columbae* from the English wood pigeon (*Columba palumbus*) would undergo sporogony in the hippoboscid, *Ornithomyia avicularia,* but 6 attempts to infect domestic pigeons by bite or injection of infected louse-flies failed.

Huff (1932) found that *Pseudolynchia canariensis* was a vector of *H. sacharovi* and used it to transmit this parasite from the mourning dove to the pigeon.

It is highly unlikely, however, that hippoboscids are the only vectors of either *H. columbae* or *H. sacharovi.* As Hanson *et al.* (1957) pointed out, hippoboscids are extremely rare on mourning doves, especially in the northern states, yet both species of *Haemoproteus* are common in them. The discovery by Fallis and Wood (1957) that biting midges (*Culicoides*) are vectors of *H. nettionis* of ducks suggests that they may also transmit *H. columbae* and *H. sacharovi.*

Altho the natural vectors of *H. columbae* and *H. sacharovi* in Illinois are unknown, the findings of Hanson *et al.* (1957) of a much higher incidence of *H. sacharovi* in considerably younger mourning doves than *H. columbae* permits one to conclude either that the vectors of the two species are different or that

TABLE 5.—Known Geographic Distribution and Prevalence of *Toxoplasma gondii* in Columborid Birds.

Country	Bird Species	Prevalence (%)		
		Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
NORTH AMERICA				
Dist. Columb.	*Columba livia*		12	
Ohio	*Columba livia*		5	
New York	*Columba livia*		1	
Tennessee	*Columba livia*		6	

(Identifications Confirmed by Mouse Inoculation, Dye Test or Both)

TABLE 6.—Known Geographic Distribution and Prevalence of *Toxoplasma*, *Lankesterella* or Similar Protozoa in Columborid Birds*.

Country	Bird Species	Prevalence (%)		
		Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
ASIA				
Portuguese India	*Columba livia*	+		
AFRICA				
Belgian Congo	*Columba livia*	+		
SOUTH AND CENTRAL AMERICA				
Brazil	*Columba livia*	+		
Panama	*Columba livia*	+		
Brazil	*Columba rufina*		88	
Brazil	*Columbigallina talpacoti*	+		

* (Identifications by Microscopic Examination Only.)

H. sacharovi has a shorter prepatent period than *H. columbae*. However, the marked difference in relative incidence in immature doves in the same locality (Hancock County) in different years (60% for *H. sacharovi* and 42% for *H. columbae* in 1952-53 as compared with 78% for *H. sacharovi* and 6% for *H. columbae* in 1954) makes it possible to speculate that the vectors may be different.

Haemoproteus columbae is only slightly pathogenic. Infected birds usually show no signs of disease. In relatively heavy infections, the birds may appear restless and go off feed, and anemia may result from destruction of erythrocytes, but this is unusual. The schizonts occur in the endothelial cells of the blood vessels of the lungs, liver and spleen. The liver and spleen of affected birds may be enlarged and dark with pigment.

H. sacharovi appears to be only slightly if at all pathogenic in the mourning dove. Becker, Hollander and Pattillo (1956) considered that it caused the enlarged, purplish livers which they encountered in dressing domestic pigeon squabs from an infected flock; there was apparently no other evidence of disease.

Leucocytozoon. A single valid species of *Leucocytozoon, L. marchouxi* Mathis and Leger, 1910 has been described from columborid birds (Levine, 1954). This species has rounded gametocytes. In addition, Minchin (1910) described but did not name a form with elongate gametocytes from a collar-dove, *Streptopelia semitorquata,* in Uganda; it has not been encountered since.

Leucocytozoon marchouxi was found in 30% of 128 *C. palumbus* in Germany by Bőing (1925); in 5% of 111 *S. orientalis* in Japan by Ogawa (1912); and in 1.2% of 392 immature and 6.5% of 72 adult *Zenaidura macroura* in Illinois by Hanson *et al.* (1957).

The known geographic distribution and prevalence of *Leucocytozoon* in columborid birds are shown in Table 4. The results of surveys in which 100 or more birds were examined have been given above. There have been only 3 such surveys—of *C. palumbus* in Germany, of *S. orientalis* in Japan, and of *Z. macroura* in Illinois. There has been a total of only 10 surveys in which 10 or more birds were examined. They involved 7 species of columborid birds in 6 countries—*Columba fasciata* in the United States, *C. livia* in South Africa, *C. palumbus* in French Morocco and Germany, *Streptopelia chinensis* in the United States, *S. orientalis* in Japan, *S. turtur* in French Morocco and Spain, and *Zenaidura macroura* in Illinois, Arizona and California.

In addition to these surveys, *Leucocytozoon* has been found in *Columba fasciata* in Colorado and Arizona or California, in *C. livia* in Pretoria, South Africa (the only record of this genus from the domestic pigeon), in *C. palumbus* in England and French Morocco, in *Geopelia striata* on Mauritius, in *Oena capensis* in South Africa, in *Sphenurus sphenurus* in India, in *Streptopelia capicola* in South Africa, in *S. chinensis* in California, in *S. senegalensis* in Upper Senegal and Nigeria, in *S. tranquebarica* in Vietnam, in *S. turtur* on Corsica and in French Morocco, Spain and Italy, in *Zenaidura macroura* in Georgia, the District of Columbia area, Arizona and California, and in *Columba argentina, C. vitiensis* and *Megaloprepia magnifica* in zoos. To these surveys should be added quite a few others in which *Leucocytozoon* was not found; those can be identified by comparison with the data on *Haemoproteus* (Table 3).

Altho Hanson *et al.* (1957) found *L. marchouxi* in a higher proportion

of adults than of immature mourning doves, they pointed out that their figures are misleading. Of the 10 infected birds in their survey, 5 were adults, 1 was a juvenile 3 to 4 months old, and 4 were nestlings. Since the great majority of immature doves in their survey were juveniles, the prevalence of patent infections with *L. marchouxi* is probably considerably less than 1% in juveniles, while that in nestlings is probably considerably more. The youngest positive dove was only 14 days old (Levine, 1954).

The vectors of *L. marchouxi* are unknown. They are presumably species of *Simulium* like the vectors of other species of *Leucocytozoon*. However, the absence of *Leucocytozoon* in columborid birds in South and Central America despite the relatively large number of surveys which have been carried out there suggests that suitable vectors may not exist in this area.

Nothing is known about the pathogenicity of *L. marchouxi*. There were no signs of illness in the infected mourning doves seen by Levine (1954) and Hanson *et al.* (1957), even tho 4 of them were nestlings and 1 was only 14 days old.

Toxoplasma, Lankesterella, and Similar Protozoa. There have been a number of reports of *Toxoplasma*, *Lankesterella* or morphologically similar protozoa in columborid birds (Tables 5, 6). Most have been in the domestic pigeon. In the great majority of cases, these organisms have been assigned to the genus *Toxoplasma*, altho de Mello (1915) called one form, which he found in a domestic pigeon in Portuguese India, a hemogregarine and de Mello *et al.* (1917) named another form from the same host *Leucocytogregarina francae*. (This generic name is no longer accepted; it is a synonym of *Hepatozoon*.) However, due to the confusion which is only now being resolved regarding the identity of these parasites, one cannot accept any identification of *Toxoplasma* in birds unless it has been confirmed by animal inoculation or by serologic means.

There have been four reports of *Toxoplasma gondii* in domestic pigeons which fulfill this requirement. Feldman and Sabin (1949) found *T. gondii* in 5% of 20 pigeons in Cincinnati, Ohio, confirming their identification by mouse inoculation. Manwell and Drobeck (1951) found *T. gondii* in 1% of 60 pigeons in Syracuse, New York, confirming their identification by use of the dye test. Jacobs, Melton and Jones (1952) found *T. gondii* in 12% of 80 pigeons in Washington, D. C., confirming their identification by the dye test and mouse inoculation. Gibson and Eyles (1957) found *T. gondii* in 6% of 16 pigeons in Memphis, Tennessee, confirming their identification by mouse inoculation.

In other reports, what may have been either *Toxoplasma* or *Lankesterella* or possibly some other genus have been found in the domestic pigeon in Portuguese India, the Belgian Congo, Brazil and Panama, in *Columba rufina* and *Columbigallina talpacoti* in Brazil, and in *Ducula concinna* in a zoo.

Discussion

A total of 174 papers is included in the present analysis. Of these, 22 are from Europe, 22 from Asia, 32

from Africa, 64 from North America, 32 from South and Central America, and 2 from Australia. This number of papers might lead one to believe that the blood parasites of columborid birds are rather well known. This is far from the case. In his *Check-list of birds of the world*, Peters (1937) listed 61 genera and 320 species of birds in the order. The most common parasite genus in these birds is *Haemoproteus*. Levine and Kantor (1959) pointed out on the basis of their compilation that *Haemoproteus* had been reported from 19 genera and 45 species of the order Columborida, but that these comprise only 31% of the known host genera and 14% of the known host species. *Plasmodium* had been reported from 20% of the genera and 7% of the species, *Leucocytozoon* from 11% of the genera and 5% of the species, *Trypanosoma* from 8% of the genera and 2% of the species, and *Toxoplasma* or something similar from 5% of the genera and 1% of the species. No parasites at all have been reported from two genera, *Oreopelia* and *Gallicolumba*, which contain 15 and 18 species, respectively, and only two cases have been reported from the genus *Ducula*, which contains 37 species.

Levine and Kantor's compilation included birds in zoos. If these are omitted, then *Haemoproteus* has been found in only 20% of the known host genera and 8% of the known host species, *Plasmodium* in 11% of the genera and 3% of the species, *Leucocytozoon* in 10% of the genera and 4% of the species, *Trypanosoma* in 8% of the genera and 2% of the species, and *Toxoplasma* or something similar in 3% of the genera and 1% of the species.

But this is not all. A great many of these records were more or less casual. The authors examined a series of blood smears from a miscellany of birds and made no attempt to identify the parasites beyond genus. Levine and Kantor (1959) found on analysis of their compilation that the parasite species had been named in 51% of 180 reports of *Haemoproteus*, 64% of 47 reports of *Plasmodium*, 32% of 31 reports of *Leucocytozoon*, 60% of 10 reports of *Trypanosoma* and 75% of 16 reports of *Toxoplasma* and similar forms. If reports on birds in zoos are omitted, these figures become 58% of 138 reports of *Haemoproteus*, 62% of 26 reports of *Plasmodium*, 35% of 26 reports of *Leucocytozoon*, 60% of 10 reports of *Trypanosoma*, and 77% of 13 reports of *Toxoplasma* and similar forms. In 43% of the total of 213 records, the species name of the parasite was not given. Furthermore, in only 41 (24%) of the 174 papers in the present analysis were 10 or more birds of a single species examined and the prevalence of infection given, and in only 12 (7%) of them were 100 or more birds examined and the prevalence of infection given.

Further light can be thrown on the reliability of our present information on geographic distribution and prevalence of these protozoa by considering the number of examinations on which it is based. I have done this for *Haemoproteus*, the genus on which we have most information. In quite a few reports, the number of birds examined was not stated and may have been relatively small. The data assembled for the

remainder are based on the examination of blood smears from 2515 birds —296 from Europe, 356 from Asia, 53 from Africa, 1391 from North America, and 419 from South and Central America. These examinations, may I remind you, were made between 1891 and 1957. A geographic distribution map might appear to be fairly well filled in, but it would be based on a pitifully small population sample.

A great deal thus remains to be done before we can claim to have really good information on the blood parasite situation in the great majority of columborid birds in most parts of the world. Casual observations are all very well, but extensive, careful, thoro surveys would be much more valuable. Furthermore, surveys made at one time of year or on one age group of host may not represent the situation at another time of year or on another age group of the same host. We lack information on all this.

Not only is our information on the geographic distribution and incidence of blood parasites of columborid birds scattered and superficial, but our information on their life cycles, vectors and pathogenesis is also poor. We do not know the role of these parasites in the interplay of favorable and unfavorable factors on which their hosts' survival in nature depends. We suspect that *Trypanosoma* and *Haemoproteus* may be relatively non-pathogenic; we think that *Plasmodium* and *Toxoplasma* may be more or less pathogenic—we know that they can be in the laboratory, at least; but we do know what to say about *Leucocytozoon* and *Lankesterella*. Here, too, more information is needed.

Another problem which needs further study is the role of the domestic pigeon as a possible reservoir of *Toxoplasma*. The surprisingly high mean incidence of 8% in a total of 176 birds examined by Feldman and Sabin (1949), Manwell and Drobeck (1951), Jacobs, Melton and Jones (1952) and Gibson and Eyles (1957) in different surveys suggest that this bird may well be an important reservoir.

Literature Cited

Adie, H. 1915. The sporogony of *Haemoproteus columbae*. Ind. J. Med. Res., 2:671-680.

Adie, H. 1924. The sporogony of *Haemoproteus columbae*. Bull. Soc. Pathol. Exot., 17:605-613.

Aragão, H. de B. 1908. Űber den Entwicklungsgang und die Űbertragung von *Haemoproteus columbae*. Arch. Protist., 12:154-167.

Aragão, H. de B. 1916. Pesquisas sobre o "*Haemoproteus columbae*." Brazil Med., 30:361-362.

Baker, J. R. 1956a. Studies on *Trypanosoma avium* Danilewsky 1885. II. Transmission by *Ornithomyia avicularia* L. Parasitology, 46:321-334.

Baker, J. R. 1956b. Studies on *Trypanosoma avium* Danilewsky 1885. III. Life cycle in vertebrate and invertebrate hosts. Parasitology, 46:335-352.

Baker, J. R. 1957. A new vector of *Haemoproteus columbae* in England. J. Protozool., 4:204-208.

Becker, E. R., W. F. Hollander and W. H. Pattillo. 1956. Naturally occurring *Plasmodium* and *Haemoproteus* infection in the common pigeon. J. Parasitol., 42:474-478.

Bennett, G. F. 1961. On the specificity and transmission of some avian trypanosomes. Can. J. Zool., 39:17-33.

Bennett, G. F. and A. M. Fallis. 1960. Blood parasites of birds in Algonquin Park, Canada and a discussion of their transmission. Can. J. Zool., 38:261-273.

Böing, W. 1925. Untersuchungen űber Blutschmarotzer bei einheimischen Vogelwild. Zentr. Bakteriol. I. Orig., 95:312-327.

Carini, A. 1912. Sur un nouvel hématozoaire du pigeon. Compt. Rend. Soc. Biol., 73:396-398.

CELLI, A. and F. SANFELICE. 1891a. Sui parassiti del globulo rosso nell' uomo e negli animali. Ann. Ist. Sper., Univ. Roma (N.S.), 1:33-63.

CELLI, A. and F. SANFELICE. 1891b. Ueber die Parasiten des rothen Blutkőrperchens im Menschen und in Thieren. Fortschr. Med., 9:499-511, 541-552, 581-586.

COATNEY, G. R. 1933. Relapse and associated phenomena in the Haemoproteus infection of the pigeon. Am. J. Hyg., 18:133-160.

COATNEY, G. R. 1938. A strain of *Plasmodium relictum* from doves and pigeons infective to canaries and the common fowl. Am. J. Hyg., 27:380-389.

COATNEY, G. R. and E. WEST. 1938. Some blood parasites from Nebraska birds. II. Am. Midland Naturalist, 19:601-612.

COUCH, A. B., JR. 1952. Blood parasites of some common Texas birds. Field and Lab., 20:146-154.

COVALEDA ORTEGA, J. and J. GALLEGO BERENGUER. 1950. Hemoproteus aviares. Rev. Iber. Parasitol., 10:141-185.

FALLIS, A. M. and D. M. WOOD. 1957. Biting midges (Diptera: Ceratopogonidae) as intermediate hosts for Haemoproteus of ducks. Can. J. Zool., 34:425-435.

FELDMAN, H. A. and A. B. SABIN. 1949. Skin reactions to toxoplasmic antigen in people of different ages without known history of infection. Pediatrics, 4:798-804.

FRANCHINI, G. 1924. Observations sur les hématozoaires des oiseaux d'Italie. (2e note). Ann. Inst. Pasteur, 38:470-515.

GIBSON, C. L. and D. E. EYLES. 1957. *Toxoplasma* infections in animals associated with a case of human congenital toxoplasmosis. Am. J. Trop. Med. Hyg., 6:990-1000.

GIOVANNONI, M. 1946. Fauna parasitologica paranaense. I. *Haemoproteus columbae* Celli e Sanfelice. 1891 em *Columba livia domestica* nos pombais de Curitiba. Arq. Biol. Tecnol., 1:19-24.

HANSON, H. C., N. D. LEVINE, C. W. KOSSACK, S. KANTOR and L. J. STANNARD. 1957. Parasites of the mourning dove (*Zenaidura macroura carolinensis*) in Illinois. J. Parasitol., 43:186-193.

HERMAN, C. M., W. C. REEVES, H. E. MCCLURE, E. M. FRENCH and W. MCD. HAMMON. 1954. Studies on avian malaria in vectors and hosts of encephalitis in Kern County, California. I. Infections in avian hosts. Am. J. Trop. Med. Hyg., 3:676-695.

HUFF, C. G. 1932. Studies on *Haemoproteus* of mourning doves. Am. J. Hyg., 16:618-623.

HUFF, C. G. 1935. *Plasmodium hexamerium* n. sp. from the bluebird, inoculable to canaries. Am. J. Hyg., 21:274-277.

HUFF, C. G. 1939. A survey of the blood parasites of birds caught for banding purposes. J. Am. Vet. Med. Assoc., 94:615-620.

HUFF, C. G. 1942. Schizogony and gametocyte development in *Leucocytozoon simondi*, and comparisons with *Plasmodium* and *Haemoproteus*. J. Inf. Dis., 71:18-32.

HUFF, C. G. and D. F. MARCHBANK. 1955. Changes in infectiousness of malarial gametocytes. I. Patterns of oocyst production in seven host-parasite combinations. Exp. Parasitol., 4:256-270.

HUFF, C. G., D. F. MARCHBANK, A. H. SAROFF, P. W. SCHRIMSHAW and T. SHIROISHI. 1950. Experimental infections with *Plasmodium fallax* Schwetz isolated from the Uganda tufted guinea fowl *Numida meleagris major* Hartlaub. J. Nat. Malaria Soc., 9:307-319.

JACOBS, L., M. L. MELTON and F. E. JONES. 1952. The prevalence of toxoplasmosis in wild pigeons. J. Parasitol., 38:457-461.

KRANEVELD, F. C. and M. MANSJOER. 1954. Onderzoekingen over bloedparasitien. VIII. Over een Trypanosoma van de tortelduif (*Streptopelia chinensis tigrina*). Hemera Zoa, 61:9-20.

KRUSE, W. 1890. Ueber Blutparasiten. Virchow's Arch., 121:359.

LAVERAN, M. A. and A. PETIT. 1909. Sur une hémamibe du *Melopelia leucoptera L.* Compt. Rend. Soc. Biol., 66:952-954.

LEVINE, N. D. 1954. *Leucocytozoon* in the avian order Columbiformes, with a description of *L. marchouxi* Mathis and Leger 1910 from the mourning dove. J. Protozool., 1:140-143.

LEVINE, N. D. and S. KANTOR. 1959. Check-list of blood parasites of birds of the order Columbiformes. Wildl. Dis., 1(1):38 pp.

MANWELL, R. D. and H. P. DROBECK. 1951. Mammalian toxoplasmosis in birds. Exp. Parasitol., 2:221-235.

MATHEY, W. J., JR. 1955. Two cases of *Plasmodium relictum* infection in domestic pigeons in the Sacramento area. Vet. Med., 50:318.

MELLO, I. F. DE. 1915. Preliminary note on a new haemogregarine found in the pigeon's blood. Ind. J. Med. Res., 3:93-94.

MELLO, I. F. DE and L. J. BRAS DE SA. 1916. A contribution to the study of haemoprotozoa in Portuguese India. Ind. J. Med. Res., 3:731-737.

MELLO, I. F. DE, L. J. BRAS DE SA, L. DE SOUSA. A. DIAS and R. NORONHA. 1917. Hématozoaires et pseudo-hématozoaires de l'Inde Portugaise. Ann. Sci. (Fac. Med.) Porto, 3:181-200.

MINCHIN, E. A. 1910. Report on a collection of blood-parasites made by the Sleeping Sickness Commission, 1908-1909, in Uganda. Rep. Sleep. Sick. Comm. Roy. Soc., 10:73-86.

NOVY. F. G. and W. J. MACNEAL. 1904a. Trypanosomes and bird malaria. Am. Med., 8:932-934.

NOVY, F. G. and W. J. MACNEAL. 1904b. Trypanosomes and bird malaria. Med. News, N. Y., 85:1144-1146.

NOVY, F. G. and W. J. MACNEAL. 1905a. Trypanosomes and bird malaria. Proc. Soc. Exp. Biol. Med., 2:23-28.

NOVY. F. G. and W. J. MACNEAL. 1905b. On the trypanosomes of birds. J. Inf. Dis., 2:256-308.

OGAWA, M. 1912. Notizen űber die blutparasitischen Protozoen bei Japanischen Vőgeln. Arch. Protist., 24:119-126.

PETERS. J. L. 1937. Check-list of birds of the world. Vol. 3. Harvard Univ. Press.

RENJIFO-SALCEDO, S., C. SANMARTIN and J. DE ZULUETA. 1952. A survey of the blood parasites of vertebrates in eastern Colombia. Acta Tropica, 9:151-169.

SANTOS DIAS, J. A. T. 1953. Resultados de um reconhecimento zoologico no Alto Limpopo efectuado pelos Drs. F. Zumpt e J. A. T. Santos Dias. V. Hematozoarios das aves: generos *Haemoproteus* Kruse e *Carpanoplasma* n. gen. Mocambique, 73:61-99.

SERGENT, ED. 1941a. Trypanosome de la tourterelle "a longue queue" *Streptopelia* sp. (?) du Sahara Nigérien. Arch. Inst. Pasteur Algérie, 19:29.

SERGENT, ED. 1941b. A propos du trypanosome de la "tourterelle à longue queue" du Sahara Nigérien. Arch. Inst. Pasteur Algérie, 19:431.

SINGH, J., C. P. NAIR and A. DAVID. 1951. Five years' observation on the incidence of blood protozoa in house sparrows (*Passer domesticus* Linnaeus) and in pigeons (*Columba livia* Gmelin) in Delhi. Ind. J. Malariol., 5:229-233.

WOLFSON. F. 1937. Experimental infections in owls and pigeons with plasmodia of the wood thrush. Am. J. Hyg., 26:53-59.

WOLFSON. F. 1940. Exo-erythrocytic schizogony associated with the wood-thrush strain of *Plasmodium cathemerium* in relation to the species of the host. Am. J. Hyg., 31(C):26-35.

WOOD, S. and C. M. HERMAN. 1943. The occurrence of blood parasites in birds from southwestern United States. J. Parasitol., 29:187-196.

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DENTAL ANOMALIES OF THE RACCOON

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Anomalies in raccoon dentition are not commonly recorded in the literature. To obviate the conclusion that such anomalies are rare, the following cases are reported. Normal dentition for *Procyon lotor*, the raccoon, as given by Goldman (1950) and by Hall and Kelson (1959), is $i\frac{3}{3}, c\frac{1}{1}, p\frac{4}{4}, m\frac{2}{2}$. No mention is made in either of these standard works of variations from this pattern.

The two skulls illustrated in Plate I, Figures 1-3, present an upper dental formula of 3-1-3-2, reflecting the absence of the first premolar on each

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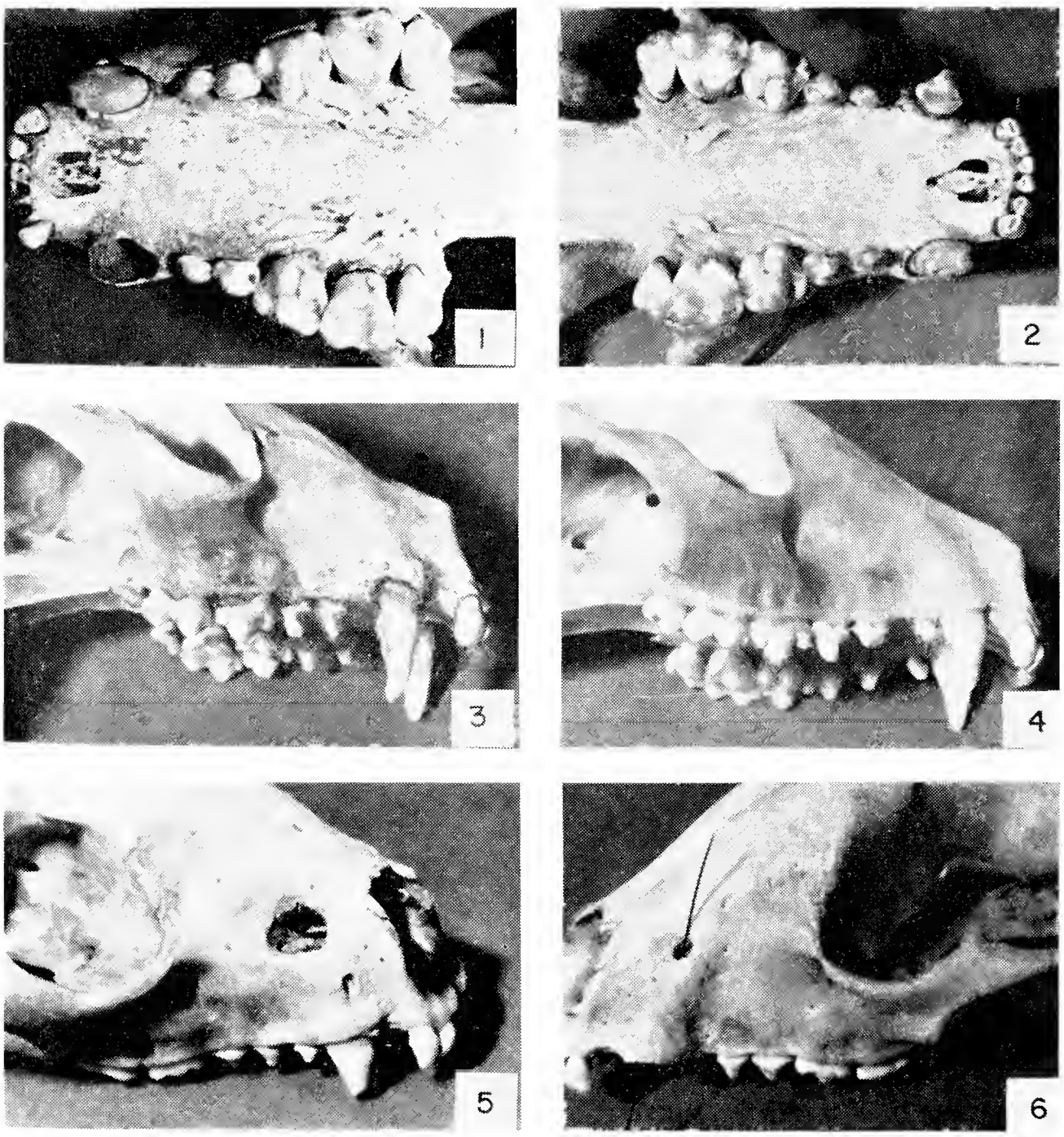

PLATE 1.—Dental anomalies in the raccoon. See text for explanation of figures.

side, though the lower jaw dentitions of these were normal. The skull shown in Figure 1, RLM No. 17, was found 5½ feet down in the gray clay of a stream bed "several miles west" of Abilene, Dickinson County, Kansas. The skull shown in Figures 2 and 3, GCS No. 2663, is from a male specimen taken in Allerton Park, near Monticello, Piatt County, Illinois.

The skull in Figure 4, GCS No. 1773, has an unusual diastema between the first and second upper premolars, the spacing causing unusually severe wear on the second upper right premolar. This was a female specimen collected several miles east of Lodge, Piatt County, Illinois.

In Figure 5, a large opening in the right maxilla exposing the base of the right canine tooth is shown. This skull, GCS No. 1788, is from a female specimen taken in Chautauqua Wildlife Refuge, Mason County, Illinois. On the left side of this skull, though not illustrated here, the third premolar is absent with a small rounded piece of tooth protruding from a tiny socket in the anterior portion of the space which would normally be filled by the third premolar, no other remnants of an alveolus being visible. This condition undoubtedly resulted from injury, an explanation not applicable for the former cases of missing teeth and alveoli.

The skull illustrated in Figure 6, RLM No. 51, was found with other skeletal remains about 40 feet inside the entrance of one of the mines in the Blackball Mine system, 1¾ miles west of Utica, La Salle County, Illinois. The opening leading from the alveolus of the left canine to the external surface of the maxilla is indicated by a horse hair. Although the bone surrounding this opening and that shown in Figure 5 does not have the spongy appearance characteristic of diseased bone tissue, the openings could have resulted from alveolar abscesses when the animals were younger, as the edges of the openings are rounded inwardly by extension of the compact bone into the openings.

The GCS skulls are from the collection of Glen C. Sanderson of the Illinois Natural History Survey, to whom the author is indebted for their loan.

Literature Cited

Goldman, Edward A. 1950. Raccoons of North and Midd'e America. North American Fauna 60, 153 pp.

Hall, E. Raymond, and Keith R. Kelson. 1959. The Mammals of North America. Vol. II. The Ronald Press Company, New York

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LEAF CHARACTERISTICS OF TWO HYBRID JUNIPERS

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The purpose of this study has been to compare and contrast the whip and scale leaves of two junipers in a natural population located approximately seven and one-half miles south of Carbondale, Illinois on limestone outcroppings on a hill near U. S. Highway 51. The stand of trees from which the two specimens were selected is a genetically mixed "swarm hybrid population" (Hall, 1952) of *Juniperus virginiana* L. (eastern red cedar) *J. Ashei* Buchh. (Ozark white cedar). The tree indicated as "*virginiana*" was chosen to represent the maximum combinations of the more typical eastern red cedar growth habit; the other tree, indicated as "*hybrid*", exhibits more apparent Ozark white cedar characteristics. Macroscopic as well as microscopic differences in leaf structure were studied.

According to Florin (1931, 1951), species of *Juniperus* exhibit four kinds of leaves: cotyledons, juvenile, transitional and mature. The transitional and mature types are frequently referred to as the whip and scale leaves respectively. Combinations of certain leaf structures of juvenile, whip and scale leaves for *J. virginiana,* and other combinations for *J. Ashei* have been assembled by Hall (1952). Structural variations of leaves from trees in natural stands deviating from these two sets of combinations are interpreted as indicators of hybridity. The combined degree of deviations is expressed as a greater or lesser tendency to resemble one or the other original parent in the presumed cross (Anderson, 1949). The selection of the two segregates used in this study rests on the assumption that it is advantageous to have plants from a similar genetic background. The two trees are the same ones sampled to point out the differences in types of shoot apices (Kaeiser, 1960). Specimens from collections are on deposit in the Herbarium of Southern Illinois University.

Acknowledgments

The writer wishes to thank Dr. Edgar Anderson and Dr. M. T. Hall for their interest in the study. Assistance from a research grant of the Illinois State Academy of Science is gratefully acknowledged.

Materials and Methods

Fresh as well as herbarium collections were used for macroscopic studies and for those under low magnification (X10-X50). For microscopic study leaves and branches were killed and fixed in F.A.A., aspirated, dehydrated in the *tertiary* butyl alcohol series and embedded in paraffin. Sections were cut approximately 10 microns in thickness and were stained in the usual manner with Safranin O and Fast Green FCF.

Figure 1 shows the general mode of branching pattern of *J. Ashei*

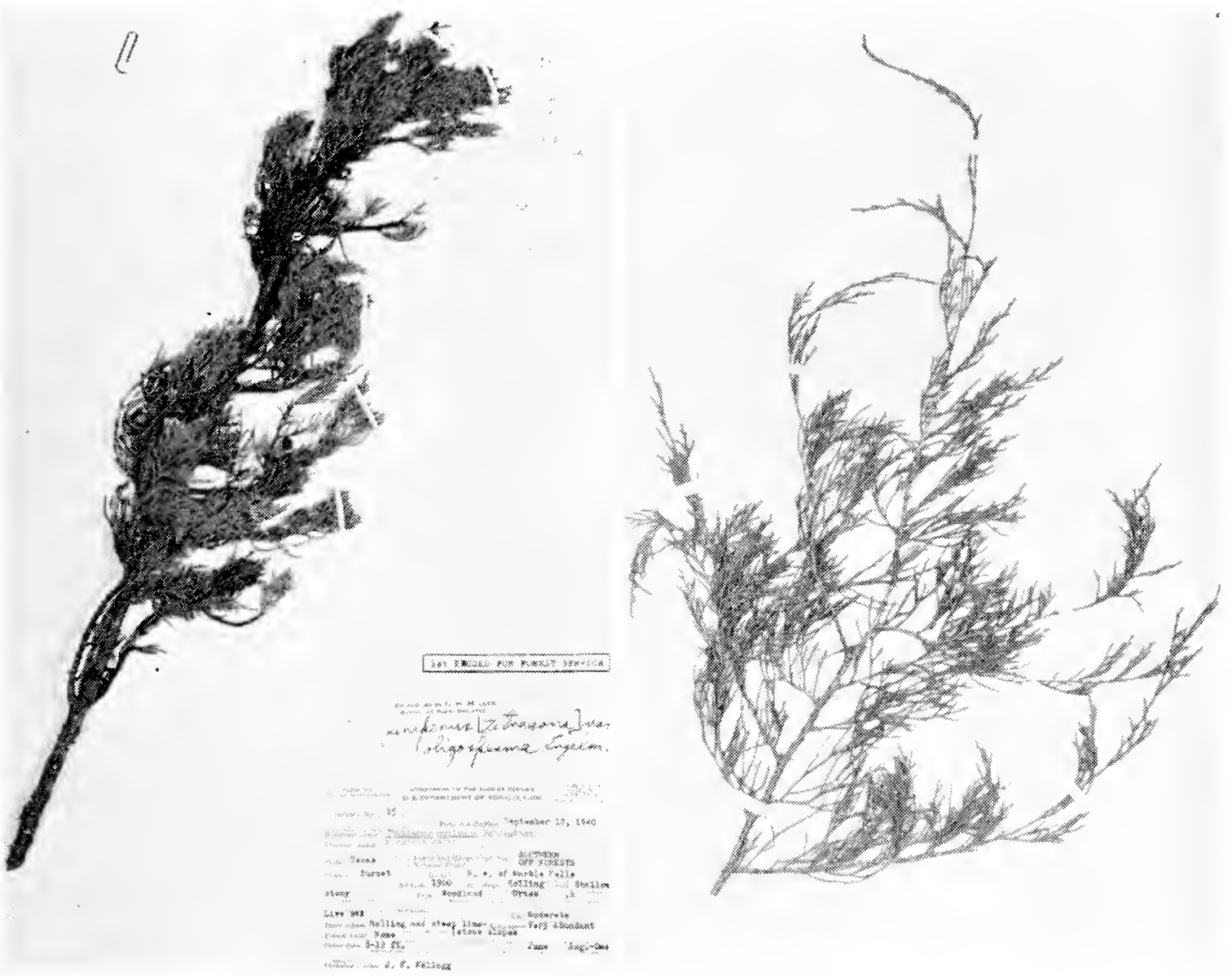

FIG. 1.—Left, *J. Ashei*; and right, *J. virginiana*.

and *J. virginiana* growing at the Kaskaskia Experimental Forest (Shawnee National Forest) in Hardin County, Illinois. Known seed source was from near Lebanon, Tennessee. Other materials of *J. Ashei*, as indicated in Table 1, were provided by G. J. Goodman from the Arbuckle Mountains of Oklahoma. Herbarium materials collected by W. W. Ashe in Arkansas and verified by Buchholz (1930) in his proposed naming of the species have been studied. Living specimens growing in Oklahoma, Arkansas and Missouri have also been observed. "Near *Ashei*" material from McVey Knob, Ozark County, Missouri was provided by Hall. The two young trees listed in Table 1, together with the mature trees indicated as "*virginiana*" and "*hybrid*", were all growing in the same stand. The older trees were approximately thirty feet in height.

Ranges in lengths of sheaths and blades of leaves found in specimens of unmixed populations of *J. Ashei* and *J. virginiana* are given by Hall. The measurements were used for comparison in the present analysis.

Figure 2 represents surface, median longitudinal and median transverse aspects of the mature stomatal apparatus on the abaxial surfaces of spur leaves of the "*hybrid*" and "*virginiana*" trees used in the study. Terminology follows that of Florin.

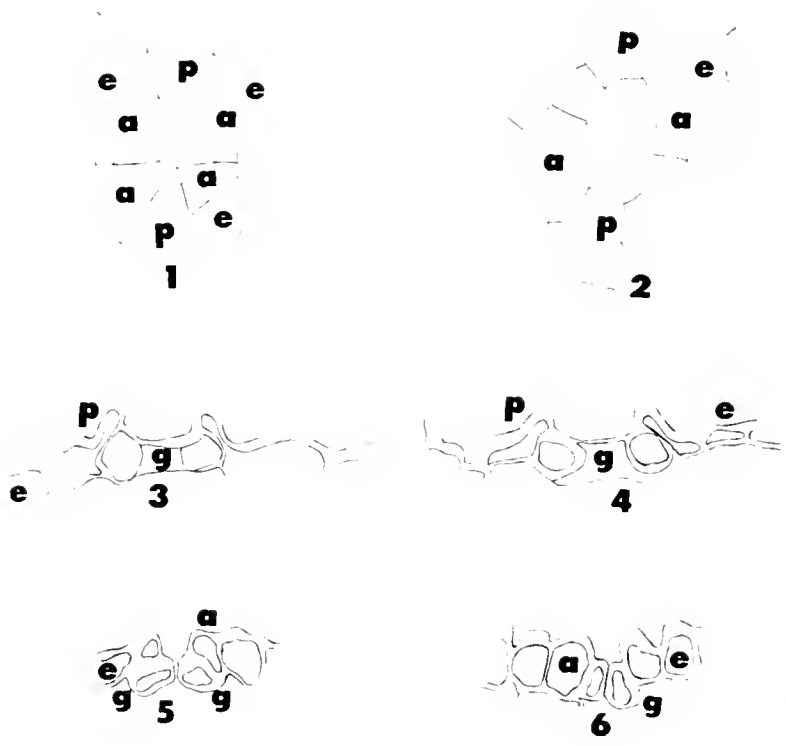

FIG. 2.—Diagram of surface view of matu e stomatal apparatus of "*virginiana*." 1. From the dorsal surface of spur leaf: a, auxiliary cell lateral to guard cell; e, encircling cell; p, polar cell. X292. 2. "Hybrid." 3. Longitudinal median section through mature stomatal apparatus of "*virginiana*." Guard cell, g. X292. 4. "Hybrid." 5. Transverse section of mature stomatal apparatus of "*virginiana*." From the dorsal surface of spur leaf: a, auxiliary cell; e, encircling cell; g, guard cell. X292. 6. "Hybrid."

OBSERVATIONS AND DISCUSSION

Among the most easily observable field characteristics in a mixed population of eastern red and Ozark white cedar are: 1) the color of foliage, 2) the proportionate lengths of the whips or terminal branches and 3) the relative amount of crowding of the lateral branches (Fig. 1; Table 1). The yellow-green rather than blue-green color, the much shorter whip branches and the very crowded appearance of lateral branches are all notable features of *Ashei* influence, and are features in the "*hybrid*" specimen chosen for detailed study. Consistent with these characteristics there are also other structural features of the whip and spur leaf types, as summarized in Table 1.

Color of foliage alone is often deceptive, and in young trees with only juvenile foliage it is not a reliable character. The relatively crowded appearance of lateral branches, as pointed out in an earlier study, is correlated with relative size and rate of growth of the shoot apices. In whip branches the shoot apex in this "*hybrid*" in vigorously growing shoots, has a wider diameter, the pith tissue is closer to the apex, and the flanking tissue (derivatives of which contribute to leaf primordia) is closer to the apex than in the "*virginiana*" specimen (Kaeiser, 1960).

Hall (1952) has shown that typical *Ashei* whip leaves have sheaths 4.0 mm and blades 3.0 mm in length, in contrast to typical "*virginiana*" whip leaves with sheaths 9.0 mm and blades ranging from 4.0-5.0 mm in length. Spur leaves of *Ashei* show 1.5 mm for sheath and 1.5 mm for blade lengths, whereas typical "*virginiana*" spur leaves have sheaths 1.0 mm and blades 3.0 mm in length. These are averages occurring in unmixed populations. When the proportionate ratios of sheath to blade lengths of whip leaves of the two trees are compared (Table 1), there is no significantly close correlation. However, there is a decided tendency exhibited in the "*virginiana*" specimen to have consistently *longer* whip leaves, so that total length is more closely related to typical eastern red cedar. Furthermore, there is a lack of any ser-

TABLE 1.—External Features of Leaves of Selected Specimens of *Juniperus*.

	General		JUVENILE LEAF							WHIP (TRANSITIONAL LEAF)							SPUR (MATURE) LEAF							
	Long Whips	Lateral Branches Crowded	Ternate	Length of Sheath (mm)	Length of Blade (mm)	Keel	Gland		Amphistomatic	Decussate	Length of Sheath (mm)	Length of Blade (mm)	Serrate	Keel	Gland		Amphistomatic	Decussate	Length of Sheath (mm)	Length of Blade (mm)	Serrate	Keel	Gland			Amphistomatic
							Oblong	Raised							Oblong	Raised							Oblong	Round	Raised	
J. Ashei Buchh. Arb. Mtns. Murray Co., Okla.	—	+																+	1.5	1.5	+	+		+	+	+
"Near *Ashei*" McVey Knob Ozark Co., Mo.	—	+																	1.5	1.5	+	+		+	+	+
"Hybrid" Jackson Co., Ill.	—	+								+	4.0	2.5	±	+	+	±	+	+	1.0	1.5	±	+		±	+	+
"*virginiana*" Jackson Co., Ill.	+	—								+	5.5	3.5	—	—	+	±	+	+	1.0	1.5	—	—	+		—	+
Juvenile 2½′ Jackson Co., Ill.	—	+	+	6.0	7.5	+	+	—	+																	
Juvenile 6′ Jackson Co., Ill.	+		+	5.0	8.0	+	+	—	+	+	3.0	3.0	—	—	+	—	+	+	1.0	1.5	—	—	+		—	+

ration on this kind of leaf, and an absence of keels on the sheaths. The presence of the latter two features are Ozark white cedar characteristics.

When the proportionate ratios of sheath to blade lengths of the spur leaves are compared, this type of leaf is found to be more like *Ashei* in both specimens. Other structures when compared indicated that the "*hybrid*" spur leaves occasionally showed both round and raised glands and had blades slightly but detectably humped. All of these characteristics are indicative of *Ashei* and all are absent in the "*virginiana*" specimen.

Both of the young trees tended to show more eastern red cedar characteristics in: 1) greater total lengths of juvenile leaves; 2) proportionate lengths of sheath to blade; 3) lack of serration; 4) lack of keels; 5) lack of round glands; and 6) glands not raised.

Aside from the differences in shoot apices referred to above, there are also consistent differences in the mature stomatal apparatus on the dorsal surfaces of the spur leaves. In following Florin's terminology the apparatus is of the haplocheilic type, and within this category is classified as amphicyclic. Surface views always disclose two polar cells, and generally two lateral auxiliary cells on either side of each pair of guard cells (Figure 2). Surrounding all of these are the encircling cells. All cells mentioned belong to the apparatus. The tendency for greater over-arching of both polar and lateral auxiliary cells in "*virginiana*" can be seen readily from Figures 3-6. There is also a tendency for greater size of this apparatus in the "*Ashei*" specimen. This is consistent with other measurements taken of ordinary epidermal cells of the dorsal surfaces of spur leaves of known *J. Ashei*.

Summary

1. In the two mature trees selected, i.e. "*virginiana*" and "*hybrid*", the former showed the tendency for whip leaves to resemble those of the genetically unmixed eastern red cedar in being of greater total length. The spur leaves, although with proportionately shorter blades than eastern red cedar, were unhumped and possessed oblong, unraised glands, all "*virginiana*" features. The "*hybrid*" whip leaves were shorter in length, some exhibiting serration and keels on the sheaths, all Ozark white cedar features. The spur leaves exhibited occasionally round and raised glands, and blades at least slightly humped, all *Ashei* features.
2. Both young trees selected tended to show more "*virginiana*" characteristics, the older one especially, as evidenced by the assemblage of six detectable morphological similarities.
3. The mature stomatal apparatus from the dorsal surfaces of spur leaves of the "*virginiana*" specimen were smaller in size than in the "*hybrid*"; both the polar and lateral auxiliary cells overarched the guard cells more in the former than in the latter. The stomatal apparatuses of "*virginiana*" are more similar to those of east-

ern red cedar, while those of the "*hybrid*" specimen correspond closely in both size and shape to those of Ozark white cedar.

Literature Cited

Anderson, E. 1949. Introgressive hybridization. John Wiley and Sons, Inc. New York, 109 pp.

Buchholz, John T. 1930. The Ozark white cedar. Bot. Gaz., 90: 326-332.

Florin, R. 1931. Untersuchungen zur Stammesgeschichete der Coniferales und Cordaitales. Svenska Vetensk. Akad. Handl. Ser. 5, 10: 1-588.

Florin. R. 1951. Evolution in Cordaites and Conifers. Acta Horti Bergiana, 15: 285-388.

Hall, M. T. 1952. Variation and hybridization in *Juniperus*. Ann. Mo. Bot. Gard., 39: 1-64.

Kaeiser, M. 1960. Shoot apices in two hybrid junipers. Trans. Ill. St. Acad. Sci., 53: 132-140.

GERMINATION CAPACITY IN AMERICAN BASSWOOD

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In the course of several years work on basswood (*Tilia americana* L.) a number of fruit collections were obtained, from many of which seed was extracted and germinated. The yield of sound seed and germination characteristics of each fruit lot were assessed as germination capacity. This capacity was related to year of collection, insect damage, geographic origin, and other factors.

Acknowledgments

This investigation was aided by grants from the National Science Foundation and from the Dr. Wallace C. and Clara A. Abbott Memorial Fund of the University of Chicago. I wish to thank the following for furnishing basswood fruits or seeds: W. L. Ashby, W. D. Bell, H. J. F. Gall, O. Vaartaja, P. D. Voth, J. C. Warden and the Central States, Northeastern and Southeastern Forest Experiment Stations of the U.S. Forest Service. Seed was purchased from the F. W. Schumacher and Herbst seed companies.

Materials and Methods

One approach was to plant untreated fruits in the garden with and without straw mulch or in flats with potting soil. The flats were retained in the greenhouse or, more usually, placed out in a coldframe. A few embryos were also dissected from seed and grown in the laboratory. The great majority of fruits was treated with concentrated nitric acid for approximately three hours, the seed shelled out, dried, treated with concentrated sulfuric acid for 15 minutes, stratified in moist vermiculite or sphagnum for three or four months at 36° F, and sown in the greenhouse or garden under presumably favorable germination conditions (Spaeth, 1934; U. S. Department of Agriculture, 1948). The germination figures reported are for the appearance of the cotyledons above ground. Sprouting of the hypocotyl which took place during stratification was generally correlated with the subsequent emergence of the cotyledons and is not reported. A trial was made of the Johnson (1946) method in which fruits were soaked in water for several days, treated with concentrated sulfuric acid for 40 minutes, rinsed, and planted.

Forty-five collections obtained during the years 1955 through 1959 included fruits from various parts of the natural distribution of American basswood, North Carolina to Manitoba and Maine to Minnesota. The fruits varied in size, extent of hairiness and persistence of the style. Samples from the various sources were retained as herbarium material by the author. The numbers of fruits within the several collections varied greatly. This in part reflected variations in fruit production from tree to tree, year to year and locality to locality.

Results

Embryos removed from the seed soon started growth on moist filter paper. In contrast, no germination was observed from untreated fruits planted in the greenhouse for periods up to 18 months. During this period the fruit coats disintegrated, but the seed remained hard. Untreated fruits planted outdoors in flats or in the garden in spring or fall of one year germinated in late April of the first, second or (in lesser numbers) third spring after planting. Germination in the first season reached 15%, in agreement with Bailey (1961).

Considerably higher germination values were found the same spring as planting for acid-treated and stratified seeds (Spaeth, 1934; Johnson 1946). In Table 1 the highest value found is 78%. Appreciable variation was noted from one seed lot to another. For those studies with acid-treated and stratified seed continued for a second spring, less than 5% additional germination was recorded. The average first season germination percentages were 39% for 1822 seed in 1957 and 34% for 1695 seed in 1958. The seedlings from various seed lots were usually very similiar in appearance. One accession of 177 seed from southeastern Wisconsin had over 10% tricot and one tetracot seedling. No other unusual types of seedlings were observed. Treatments given to stratified seed after spring planting, such as mulching with straw or shading (Ashby, 1961), resulted in less rapid emergence but approximately equal final numbers of seedlings.

Additional factors were of importance in determining basswood's regenerative capacity (Table 1). The several collections totalling several thousand fruits varied in yield of sound seed from zero to nearly 100%. Filled fruits were usually one-seeded. Collections yielding high percentages of fruit with seed often had several percent of fruit with double or even triple seed. Seed quality varied from nearly 100% sound to 100% which rotted when stratified after acid treatment. Some otherwise sound seed lots had up to 30% insect infestation. An apparent yearly correlation in Table 1 of high percentages of multiple-seeded fruit and high values of damaged or unfilled seed was not true for individual seed lots. Ground collections, while sometimes good, tended to give poorer seed yields than tree collections. Average seed weights for 13 collections in 1958 varied from 12 to 38 mg with an average of 31 mg.

Fruit production, which was found on some trees in the Chicago region each year of the study, occurred with greatest abundance in 1957. Collections made from a single tree in southern Wisconsin had many poorly-filled seed and no multiple-seeded fruits in 1956, while in 1957 fruits were greater in amount with no poor seed and some multiple-seeded fruits. On a trip in October, 1958 to parts of Iowa, Minnesota, and Wisconsin, I found only one tree with fruit out of hundreds of trees examined.

Comparisons of fruit quality for individual trees are illustrated by data from four trees in a small valley in the St. Lawrence River sec-

TABLE 1.—Characteristics of Basswood Fruits and Seeds.

Characteristic	Year of Collection			
	1955	1956	1957	1958
Number of collections with				
Seed yield 0-33%	7	1	2	2
Seed yield 34–67%	0	3	2	3
Seed yield 68–100%	1	2	10	4
Percent of the above collections with				
Multiple-seeded fruit	0%	33%	21%	11%
Seed poorly filled, insect damage, etc.	25%	83%	57%	44%
Percent germination of				
Apparently sound acid-treated and stratified seed	0-70%	0-78%	0-52%	0-20%*

* Germination in garden rather than greenhouse.

tion of New York State. Seed yield in 1958 ranged from 100 to 5% and emergence in the garden for apparently sound stratified seed from 15 to 0%. The tree yielding 100% seed per fruit had multiple-seeded fruit and some poorly filled seed. Most of the seed from the poorest yielding tree were poorly filled.

Basswood germination was observed each spring in several field areas of the Chicago region. The numbers varied from year to year. Only one instance of very abundant basswood seed germination was found. This occurred in a presumably protected area in southwestern Michigan which had been invaded by campers the previous autumn. The nature of the altered seed bed was not determined.

DISCUSSION

Germination capacity in basswood is related to the several factors studied: fruit production, numbers of seed per fruit, percent of sound seed, and germination percentage (Spaeth, 1934). The delayed germination leads to annual appearance of seedlings despite the yearly variations in fruit production and quality. Other investigators (Den Uyl, *et al.*, 1938; Hart, 1958, 1959; McConkey, 1960, 1961; Rudolph, 1950-61; Spaeth, 1934) have reported marked annual and geographic variation in fruiting of forest tree species, including basswood. Factors outside the scope of the present investigation which determine regeneration capacity include animal use of seed (which I have observed on occasion to be extensive), distribution of seed to favorable sites, and suitable soil and climatic conditions. My present concept is that in the Chicago region the production and germination capacity of American basswood seed is rarely a substantial limiting factor where mature trees are found. I am not yet satisfied that such is the case in southern Illinois.

A second type of regeneration in basswood involves sprouting from the base of the trunk. This serves to maintain the species, once established. In only one instance was such a sprout found as far as one foot from a trunk. If true root sprouts occur, they are rare in comparison to the common trunk sprouts.

Length of the stratification period was not systematically studied for its effect on germination. This probably affected the absolute performance of one seed lot versus another. My criterion for removing the seed from stratification conditions and planting them was evidence of growth by the radicle. As a rule several seed lots were removed at one time. The percentages of seed in which growth of the radicle was evident might differ for the several seed lots. Seed for comparative tests were sorted for response to stratification and the treatments were given to representative groupings. I did find that "hard" seed may give very low emergence percentages after a stratification period which leads to good emergence by seed on which sprouting is evident. Thus intra-seed-lot differences need to be considered in evaluating inter-seed-lot performance. A requirement for prolonged stratification (Spaeth, 1934) would influence the germination capacity of individual seed.

Summary

Basswood fruit collections varied in seed yield from 100% to 0%. Germination of acid-treated and stratified selected seed ranged from 78% to 0%. Fruiting alone is not a satisfactory measure of basswood seed production and quality. Delayed germination can lead to annual appearance of seedlings despite the yearly variations in seed production and quality.

Literature Cited

Ashby, W. C. 1961. Responses of American basswood seedlings to several light intensities. Forest Science, 7: 273-281.

Bailey, C. V. 1961. Early collection and immediate sowing increase germination of basswood seed. Tree Planters' Notes, 46:27-28.

Den Uyl, D., O. D. Diller, and R. K. Day. 1938. The development of natural reproduction in previously grazed farmwoods. Purdue Univ. Agric. Exp. Sta. Bul. 431, 28 pp.

Hart, A. C. 1958. Report on 1957 forest tree seed crop in New England. U. S. Forest Service. Northeastern For. Exp. Sta., For. Res. Note No. 79, 2 pp.

Hart, A. C. 1959. Reports on 1958 forest tree seed crop in New England. U. S. Forest Service. Northeastern For. Exp. Sta., For. Res. Note No. 86, 2 pp.

Johnson, L. P. V. 1946. A practical method of overcoming seed dormancy in *Tilia americana* L. Forestry Chronicle 22:182-190.

McConkey, T. W. 1960. Report on 1959 forest tree seed crop in New England. U. S. Forest Service, Northeastern For Exp. Sta., For. Res. Note No. 96, 3 pp.

McConkey, T. W. 1961. Report on 1960 forest tree seed crop in New England. U. S. Forest Service, Northeastern For. Exp. Sta., For. Res. Note No. 115, 3 pp.

Rudolph, P. O. 1950-1961. Reports on forest tree seed crop in the Lake States. U. S. Forest Service, Lake States For. Exp. Sta. Tech. Notes No. 333, 349, 370, 393, 412, 426, 447, 501, 540, 565, 574, and 598.

Spaeth, J. N. 1934. A physiological study of dormancy in *Tilia* seed. N. Y. Agric. Exper. Sta. (Ithaca). Memoir 169, 78 pp.

U. S. Dept. Agric. 1948. Woody-Plant Seed Manual. Misc. Publ. 654. G. P. O., Washington, D. C., 416 pp.

COMPARATIVE EFFECTIVENESS OF DDT SELECTION METHODS IN *DROSOPHILA MELANOGASTER* MEIGEN

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Insect resistance to a variety of poisons has been known since the early part of the century. Brown (1957, 1958) has summarized the widespread resistance of various insects to the newer synthetic insecticides. This study bears on two questions concerning evolution of resistance to DDT by *Drosophila melanogaster* Meigen. It is of importance (1) to know whether a mixed population of flies known to contain genes (from several sources) conferring resistance to DDT, would show different rates of gain and level of resistance under different methods of selection applied under similar culture conditions, and (2) to determine the maximum degree of resistance obtainable by selection of such a population.

Methods and Materials

Three strains of DDT-resistant *Drosophila melanogaster* were taken from stock culture in October, 1959 and mixed to form one heterogeneous stock. The three lines, HL2-top (Bennett, 1960), Brown eye-R (Crow, 1954), and ORS-1001 (King, 1957), had been cultured and tested earlier by Bennett (1960, and unpublished data). The mixed stock was then divided among three population cages.

The flies used in this study were raised in 8 dram straight-walled glass shell vials (25 x 95 mm), each of which contained approximately ¾ of an inch of food medium, and polyethylene population cages (Bennett, 1956). The standard food medium consisted of 18 g of agar, 60 cc of sugar, 100 cc of brewer's yeast in 1000 cc of water. For the first five generations, 5 cc of propionic acid was added as a mold inhibitor, for the last 5 generations, 15 cc of 10% Moldex in alcohol was substituted. Culture vials were seeded with dry yeast (Schlitz, brewer's yeast) before use. This study covered a ten month period (October, 1959 to July, 1960).

In the ninth generation tests, a disproportionately large kill occurred when the temperature in the incubator rose from the normal of 25° to 29° C (a known cause of increased mortality, Barker, 1957).

The "holding food" was similar to the above described "regular" food except that the yeast was omitted. The test vials contained filter paper impregnated with DDT crystals deposited from acetone solution. A test set consisted of three such vials with concentrations of 1, 25, 625 μ g DDT/cm^2. Data from each test set covered three concentrations and LD_{50} value were thus established. General testing procedures followed those used by Bennett (1960), and Coomes and Bennett (1960). The LD_{50} value of a particular test set was based on the performance of at least nine and nor-

mally 18 flies. At least three flies per vial were tested and not more than six flies per vial were used.

In the sib-selection line, values were obtained for each sibship based on one test set. These values provided the basis for selection of the sibships to provide parents for the next generation. The values presented here are based on summation of survival values at each concentration in all of the test sets used for a particular line or cage in each generation.

All testing was done on female flies as Crow (1954) has shown that the results obtained are more reproducible than when males are used. The females tested were of varying ages. Those from the progeny of pair matings raised in standard food vials were approximately two days old.

Methods of Selection

Tests were made on each of the three cages for two consecutive generations to determine a base point of DDT resistance for each cage.

Cages 1 and 2 were designated as control cages and cage 3 as the permanent DDT cage A DDT vial (3,050 μg DDT/cm^2) was attached to this cage throughout the period of study, beginning with test generation one. A new DDT paper was introduced twice, in the fifth and ninth generations. Eight to twelve food vials were attached to each cage. Samples were obtained from each cage at every generation by etherizing the whole cage.

After determining the base point of resistance, a direct selection line was established by taking the top 30 females which survived the highest concentrations of DDT from the sets from cage 3. Males were taken directly from cage 3. Of the 30 females, six were placed in each of five vials along with males. After a two-day period of egg laying, the flies were transferred into another five vials, providing a larger population of flies for testing. Each succeeding generation was established in the same way without going back to cage 3. Thus, female survivors of a given test were used as parents of the next generation and were mated to untested males of the same generation. This provided direct selection for DDT-resistance exhibited by survivors (and male offspring of the previous generation's survivors) that had been raised in standard food vials.

The sib-selection line was established with 60 pair matings in standard food vials from cages 1 and 3. Thirty females from cage 1 were mated to 30 males from cage 3. The reciprocal crosses were also made, insuring a comparable sample from both cages. Thus, each of 60 pairs of flies was allowed to produce one progeny (sibship, family) in one food vial. Of the 60 the 40 largest progenies were tested for DDT tolerance. Nine to 18 females were taken from each progeny and tested. After the results were recorded, the progenies were ranked according to their DDT tolerance, based on the performance of the females tested. The top 20 progenies were broken down into the "top five" and the "next 15". From the top five cultures showing most resistance, 30 pair matings were made, using six pairs from each progeny. The next

15 progenies each contributed two males and two females (30 pair matings) to the next generation. For the first five generations males and females were taken from the same progenies, thus inbreeding by brother-sister mating. In the last five generations, the males and females from each progeny were mated serially. In each case the flies were mated with one pair to each food vial. The result was 60 vials, each with a pair of parents, to produce 60 progenies, 40 of which would be tested the next generation. This indirect selection was repeated in each generation. Individuals of the germ line were never exposed to DDT.

In each generation, 40 test sets were made from the sib-lines raised in vials, 20 test sets from control cage 1, and 20 test sets from cage 3, the permanent DDT cage. Any remaining test sets were used for the testing of control cage 2. Cages 1 and 3 never required 20 test sets, so in each generation a number were used for control cage 2.

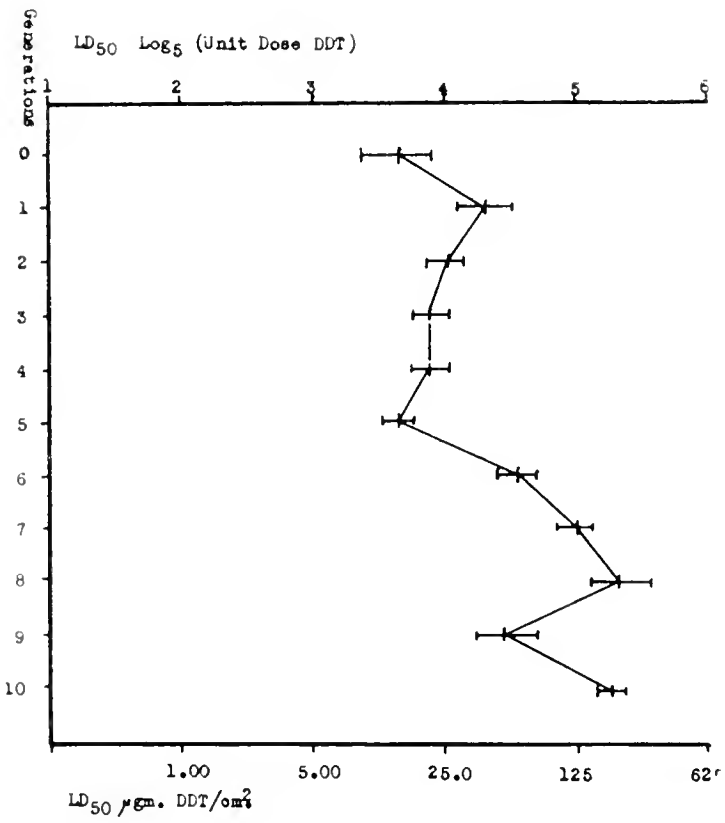

FIG. 1.—Results of testing sib-selection line for DDT tolerance for 18 hour period. Mean and 95% confidence limits indicated.

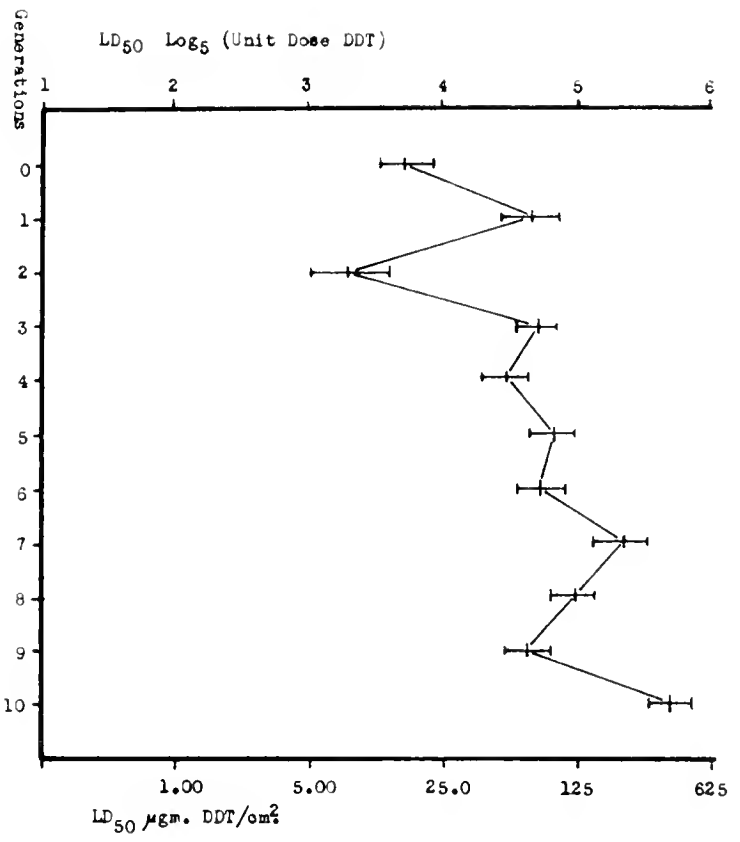

FIG. 2.—Results of testing direct selection line for DDT tolerance for 18 hour period. Mean and 95% confidence limits indicated.

RESULTS

The principal results of this study are summarized in Figures 1, 2, and 3.

The course of selection through 10 generations of the sib-selection line is shown in Figure 1. During the first five generations of selection, brother-sister pairs were used as parents. This inbreeding prevented any net gain in resistance. Starting with the parents of generation 6, random mating was instituted. All of the observed gain of resistance in this line occurred following this change of mating system.

The direct selection results are shown in Figure 2. No change of mating system occurred in this line

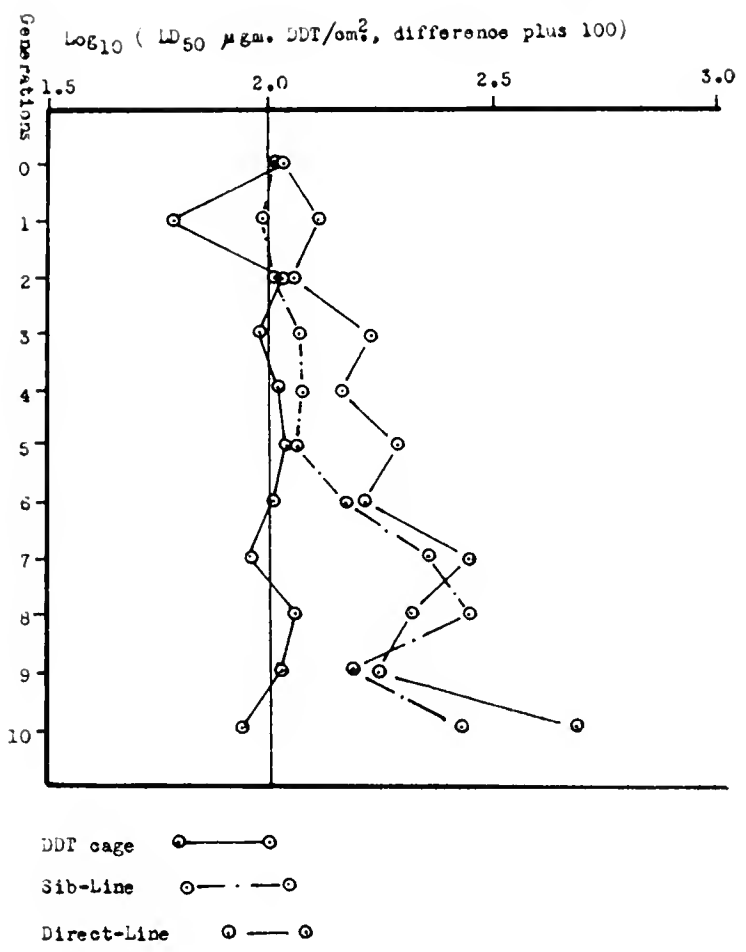

FIG. 3.—Results of the difference (plus 100) between the values (In μ g DDT/cm²) of the control cages and the experimental lines tested for DDT tolerance for 18 hour period.

and, despite gross fluctuations, the gain was more evenly distributed through the selection period.

Figure 3 presents the material in different form, and with the results from cage 3 for comparison. The base line in Figure 3 was established by taking the combined test results of the two control (unselected) population cages (1 and 2), subtracting that value for each generation from the values of the other indicated lines, adding 100 to eliminate negatives, and expressing the results as logarithms to the base 10.

DISCUSSION

The second objective of this study, to produce a selected line of *Drosophila melanogaster* more resistant than any previously tested, was clearly achieved. The LD_{50} of the direct selection line in the 10th generation was 5.70 ($\log_5$ unit dose DDT; 385.6 μ g DDT/cm²) and of the sib-selection line, 4.81 ($\log_5$ unit dose DDT; 189.92 μ g DDT/cm²). In a comparative study of resistant lines from Japan and two laboratories in the U.S. (Bennett, 1960) the two most resistant stocks showed values of 4.50 and 5.49 ($\log_5$ unit dose DDT; 55.9 and 276.8 μ g DDT/cm²). Thus the most resistant line in this study was nearly 40% more resistant than any previously reported line. The three DDT resistant lines that were the progenitors of the starting population in this study had the following LD_{50}'s when tested in 1957 (Bennett, 1960): ORS 1001, 5.49 (276.8 μ g DDT/cm²); Brown-eye-R, 3.68 (14.99 μ g DDT/cm²); HL2-Top, 3.35 ($\log_5$ unit dose DDT; 67.8 μ g DDT/cm²). The values achieved by direct selection surpassed the highest value shown by these lines in the past. This is interpreted as indicating that some degree of integration of the resistance factors of the parental lines had been achieved, combining separate resistance mechanisms for a superior total resistance.

Comparative tests using the mosquito test kits provided by the World Health Organization showed that the least resistant parental line used here required several times the DDT exposure recommended for resistant mosquitoes to achieve a significant kill. Thus it is apparent that *Drosophila melanogaster* has achieved much higher tolerance to this insecticide than have mosquitoes (Coomes and Bennett, 1960).

The primary objective of this paper has been only conditionally satisfied. The final degree of resistance exhibited by the direct selection line was considerably higher than that of the sib-selection line. The increase in DDT resistance over that of the starting population was 23-fold for the direct-selection line and 13-fold for the sib-selection line. However, the inbreeding in the first five generations of selection in the sib line prevented any net increase in resistance, so the 13-fold gain was attained in the final 5 generations. This compares with a 5.5-fold increase for the direct line in the first five generations and a 4-fold increase in the final five generations. Thus one could argue that sib-selection had demonstrated greater rate of gain during the final five generations than direct-selection produced in either 5 generation period.

The evidence thus does not provide a delineation of the relative effectiveness of the two selective methods. It is clear that both methods can be highly effective under the conditions used.

Figure 3 shows that the population in the DDT Cage did not gain in resistance during this study. This population was highly resistant at the start and it appears that the rate of kill (observed to be very low) produced by the DDT lined vial in the cage was so low as to provide no effective degree of selection. This is of interest because Bennett (1960) had attempted earlier to compare effectiveness of sib-selection in pair matings in vials with direct-selection in population cages (of a different design than those used here). The comparison did not seem a good one at the time, but was used as the only one available in the data at hand. In this study we have been able to make a partial comparison using flies raised in vials on the same batches of food. We know that a difference in population density existed in the culture vials of the direct and sib-selection lines. In future work the differences of population density and of mating pattern will have to be dealt with.

Acknowledgment

The authors wish to acknowledge the support of the National Science Foundation, through Grant No. 8708, and of the Northern Illinois University Biology Department, in providing laboratory facilities.

Summary

A heterogeneous population of *Drosophila melanogaster* was produced by mixing three DDT-resistant strains. This hybrid population was divided into sub-populations by culturing them in two control population cages and a third population cage containing a permanent DDT lined vial. A sib-selection line and a direct-selection line were tested for DDT resistance each generation. Selection was carried on for ten generations. During the first five generations the sib-line was inbred (brother-sister pair matings) whereas the last five generations out-breeding (between families within the line) was used.

At the end of the selection period, the DDT cage population showed a DDT tolerance 0.46 times that of the starting population. The sib-selected

line showed no increase in the first five generations due to inbreeding, but a 13-fold increase in tolerance was attained by five generations of out-breeding and selection. The direct-selection line reached a 23-fold increase in resistance at the end of ten generations of selection. However, in the five generations of effective selection, the sib-selection line increased resistance by more than twice as much as the direct-selection line in a comparable five generations.

The direct-selection line attained a higher degree of tolerance to DDT than any single resistant strain tested earlier. Thus the different resistant genotypes were recombined in a way which yielded a higher degree of resistance than had been attainable by any one selected line.

In this study sib-selection appears to be a more effective method of selecting DDT-tolerant genotypes than the direct-selection method.

Literature Cited

Barker, Roy J. 1957. Some Effects of Temperature on Adult House Flies Treated with DDT. *Journal of Economic Entomology* 50 (4): 446-450.

Bennett, Jack. 1956. Inexpensive Population Cages. *Drosophila Information Service* 30: 159-60.

Bennett, Jack. 1960. A comparison of Selective Methods and a Test of the Pre-Adaptation Hypothesis. *Heredity* 15(1): 65-77.

Brown, A. W. A. 1957. Insecticide Resistance and Darwinism. *Botyu-Kagaku*, 22: 277-282.

Brown, A. W. A. 1958. Insecticide Resistance in Arthropods. W. H. O. Monograph Ser., No. 38, 240 pp.

Coomes, R. K. and Jack Bennett. 1960. Use of World Health Organization Mosquito Test Kit with DDT Resistant *Drosophila*. *Trans. Ill. St. Acad. Sci.* 52 (3 & 4): 151-155.

Crow, J. F. 1954. Analysis of a DDT-resistant Strain of *Drosophila*. *Journal of Economic Entomology* 47: 393-398.

King, James C. 1957. Investigation of the Genetic Nature of Resistance to Insecticides Developed by Populations of *Drosophila melanogaster*. Final report of research carried out by Long Island Biological Association for Medical Research and Development Board, Office of the Surgeon General, Department of the Army.

OXYGEN CONSUMPTION IN THE SMALL, SHORT-TAILED SHREW (*CRYPTOTIS PARVA*)

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Interest in the increase of metabolic rate with decrease in body size of mammals and other organisms has stimulated investigation of oxygen consumption in very small mammals. Several species of the shrew are representative of the smallest living mammals, and consequently are unique for such experimentation.

Comparative studies of oxygen consumption of the wandering shrew (*Sorex vagrans vagrans*), the Monterey shrew (*Sorex trowbideii monteryensis*), and the Sonoma shrew (*Sorex pacificus sonomae*) have been reported by Pearson (1948). Also, the rate of oxygen consumption has been determined for the long-tailed shrew (*Sorex c. cinereus*) by Morrison (1948). Reports are lacking, however, in regard to one of the smallest species of shrews, the small, short-tailed shrew (*Cryptotis parva*). Thus, it is the purpose of the present communication to report on the oxygen consumption of three small, short-tailed shrews, as determined in the apparatus of Watts and Gourley (1953).

Materials and Methods

Three captive wild specimens of the small, short-tailed shrew (*Cryptotis parva*) were utilized for all experiments. One adult female of undetermined age was tested in the post-lactational stage, and two, six-to seven-week old weanlings from the litter of the adult female were studied initially. Oxygen consumption determinations were subsequently carried out on one of the shrews from the litter at the age of about four months. At this time the shrew was full-grown and was proven to be a male. A total of eighteen experiments were run. All animals were sustained on live insects, ground beef, and water. However, the shrews were not fed two to three hours prior to the experiments in order to provide a post-absorptive state.

The apparatus employed was similar to that used by Watts and Gourley (1953), except for the following modifications. A 375 ml dark-tinted jar with a number 10 rubber stopper, a standard 5 ml pipette, and an aluminum screen wire grid were utilized. In addition, the cylindrical wire compartment was eliminated so that the shrew was allowed freedom of movement. This apparatus utilizes a layer of soda lime (8 mesh) beneath the wire grid to absorb carbon dioxide. The rate of oxygen consumption can be determined since the volume of oxygen consumed is measured by the excursion of a moveable soap film in the pipette. Watts and Gourley (1953) have demonstrated with the rat that this apparatus is of adequate reliability and sensitivity for determination of oxygen consumption in small mammals.

Ten minutes were allowed for temperature equilibration, and the duration of each experiment was equal to the time for the utilization of 5 ml of oxygen.

Results

The results are given in Table 1. It is evident that oxygen consumption increases greatly with increased activity. Indeed, the rate of oxygen consumption in the adult male shrew almost doubled from a *basal* rate of 7.0cc/g/hr to 13.2cc/g/hr under conditions of vigorous activity. Due to the normal incessant activity of shrews in the waking state, it is probably impossible to simulate conditions with the shrew that are characterized as *basal* with other less active mammals. It was found that slight changes in activity of the test animals caused immediate alterations in oxygen uptake, as registered with the soap film excursions. Shrews in the respirometer generally were very active and frequently chewed on the screen grid or rubber stopper. In a few instances general activity was relatively low and as indicated in Table 1, a subjective rating of *slight* activity was applied to shrews at comparative *rest*.

Discussion

It has been demonstrated by Hamilton (1944) and others that the rate of digestion in shrews is exceedingly rapid. In one instance Hamilton (1944) observed that the passage of chitin through the alimentary tract in a captive, non-fasted shrew required only 95 minutes. The shrews used in the present investigation

Table 1.—Oxygen Consumption of Small, Short-Tailed Shrew (*Cryptotis parva*) as Related to Activity.

Animal	Weight (g)	Air Temp. (°C)	Number Experiments	Standard Deviation	Activity[1]	Mean O_2 Consum. (cc/g/hr)
Adult Female	6.02	25	2	.39	Moderate	9.4
Adult Female	6.02	25	4	.97	Vigorous	11.4
Adult Male	6.36	27	5	.78	Slight	7.0
Adult Male	6.36	26	5	.57	Vigorous	13.2
Immature Shrews[2]	a 4.59	25	1	..	Vigorous	11.9
	b 4.73	25	1	..	Vigorous	10.4

[1] Activity was subjectively rated: slight, shrew at rest; moderate, shrew walking or chewing on grid half time; vigorous, shrew constantly and vigorously chewing on grid.

[2] Sex undetermined.

probably were in a post-absorptive state, since they had not been fed two to three hours prior to each determination. However, true *basal* conditions were approached only during five experiments with the adult male shrew at the periods of least activity. This lack of muscular repose in the shrew during metabolism determinations has also been encountered by other investigators (Morrison, 1948).

The results of the present report are in accord with those of other investigators (Morrison, 1948; Pearson, 1938). The oxygen consumption of 7.0cc/g/hr for the 6.36g *Cryptotis parva* at *basal* conditions falls on the curve constructed by Pearson (1948) where oxygen consumption of small mammals is plotted as a function of body weight. Also, the high oxygen utilization of 13.2cc/g/hr obtained during those experimental runs characterized by vigorous shrew activity can be compared to the oxygen utilization of 13.7cc/g/hr for the long-tailed shrew (Morrison, 1948).

Summary

The normal rate of oxygen consumption was determined in three small, short-tailed shrews (*Cryptotis parva*), one of the smallest species of shrews. Determinations were obtained for both immature and adult male and female shrews in the post-absorptive state, and in varying degrees of activity. A simple closed chamber basal metabolism apparatus was utilized for the determinations. Mean oxygen consumption rates of 7.00cc/g/hr in the *resting* state and as high as 13.2cc/g/hr in states of vigorous activity were calculated.

Literature Cited

Hamilton, W. J. 1944. The biology of the little short-tailed shrew, *Cryptotis parva*. J. Mammal., 25:1.

Morrison, P. R. 1948. Oxygen consumption in several mammals under basal conditions. J. Cell. and Comp. Physiol., 31:281-292.

Pearson, O. P. 1948. Metabolism of small mammals, with remarks on the lower limit of mammalian size. Science, 108: 44-46.

Watts, D. T., and D. R. H. Gourley. 1953. A simple apparatus for determining basal metabolism of small animals in student laboratory. Proc. Soc. Exp. Biol. and Med., 84:585-586.

NOMENCLATURE OF THE LATE MISSISSIPPIAN WHITE PINE SHALE AND ASSOCIATED ROCKS IN NEVADA

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Late Mississippian detrital rocks in eastern and southern Nevada and adjacent California have been assigned to at least nine different formations and there is no concensus regarding their classification. Although our current investigations are incomplete (Langenheim, 1956a, 1956b, 1960) my own prior use of the classification proposed in this paper (Langenheim and Tischler, 1960; Langenheim *et al.*, 1960), imminent use by fellow workers and needs arising from preparation of a correlation chart for the Great Basin by a committee of the Eastern Nevada Geological Society require preliminary publication of nomenclatorial problems regarding these rocks.

The Late Mississippian detrital rocks of the central Great Basin consist of a basal calcareous siltstone unit, a black fissile shale unit, a sandy shale unit and an upper sandstone and conglomerate unit (Figs. 1, 2). The sequence as a whole generally thickens toward the west and the upper, coarser members increase in relative importance. The basal, calcareous siltstone unit, however, thickens eastward and at least one interbedded limestone unit occurs within the black fissile shale unit in eastern Nevada. The entire detrital sequence rests disconformably on Early Mississippian or older rocks and appears gradational with overlying later Paleozoic carbonate rocks. A disconformity may be present either at the base of the sandy shale unit or within the conglomerate and sandstone unit, but this has not been fully demonstrated.

History of the Nomenclature

The first significant account of the late Mississippian rocks in the Great Basin is that of the King Survey (Hague, 1870; Hague and Emmons, 1877; King, 1876), in which Hague (1870) mapped and described the White Pine Mining District. Here he recognized, in ascending order, a calcareous shale, a siliceous limestone, an argillaceous shale divided into a lower "bituminous" portion and an upper sandy portion, a "reddish yellow" sandstone and Carboniferous limestone. Hague's map and descriptions (1870: 409-421, Atlas Sheet 14) permit ready identification of his units on the ground and correlation with Humphrey's (1960) recent description and map. Furthermore, Hague appears consistent in his own terminology and apparently always refers to these units as "calcareous shale", "siliceous limestone", etc. in later publications and in conjunction with formally proposed stratigraphic names. Thus the "White Pine Shale" of Hague is

always described as composed of argillaceous and sandy shale in the White Pine District.

Hague (1882) first used the name "White Pine Shales" in a brief administrative report in which he refers to "black argillaceous and arenaceous shales which overlie the limestone" to the "White Pine Shales." He also states that these rocks are named "White Pine shales from the locality where they were first recognized in Eberhardt Cañyon, and underlying the town of Hamilton" (Hague, 1882: 28). In later work Hague refers to sections in Applegarth Canyon which is a strike valley in the White Pine Shale trending south from Hamilton. Applegarth Canyon is shown as the upper part of Cathedral Canyon in the Treasure Hill (edition 1950) and Illipah (edition 1951) 15 minute series topographic maps of the U. S. Geological Survey. One year later, Hague (1883), in an "Abstract" of his forthcoming monograph on the geology of the Eureka District, described the White Pine Shale as a "heavy body of black shale . . . having been first recognized as a distinct horizon in the White Pine Mining District." This latter reference is cited in Wilmarth (1938) as the first reference to the White Pine Shale. Although these two citations and the 1870 description of the White Pine District clearly identify the rocks upon which Hague's concept of the White Pine Shale rests, some confusion has arisen because the 1882 and 1883 papers were chiefly concerned with the geology of the Eureka District. This has led some to accept exposures in the southern Diamond Range as the type locality or the most important reference locality for the White Pine Shale concept.

In 1883 Hague first applied the name, "Diamond Peak Quartzite", to the sandstone and conglomerate resting on the White Pine Shale at Eureka and in the White Pine District. Previously these rocks had been referred to as "reddish yellow Sandstone" (Hague, 1870), "Ogden quartzite" (Hague *in* King, 1880: 27) and "Weber quartzite" (Hague, 1882).

In 1892 Hague fully described the Eureka District, redescribed the rocks of the White Pine District and discussed correlation between these two areas and other localities. The section at Sugar Loaf in Packer Basin near Eureka, important in nomenclatorial problems, is described on page 81 as paraphrased below:

Top

1. Shaly sandstone with interbedded shale and conglomerate..1,000 feet.
2. Black argillaceous shale with gradational upper contact.. 400 feet.
3. Gray crinoidal, sandy limestone with *Chonetes* ..... 50 feet.
4. Yellow-weathering, black, argillaceous and calcareous fossiliferous shale ..... 300 feet.
5. Blue, fossiliferous limestone.. ..... 250 feet.
6. Siliceous limestone..... 150 feet.

Bottom

Hague (1892: 80-81) somewhat ambiguously remarks that the "beds directly underlying the shale are of course the uppermost members of the Nevada limestone." From this and from his correlation of the Packer Basin section with the section in Applegarth Canyon in the White Pine District, it is apparent that units 1-4 are considered part of

the White Pine Shale and 5-6 are part of the Nevada limestone.

Thus, in regard to the Applegarth Canyon Section in the White Pine District, Hague (1892: 193) states, "A more characteristic White Pine fauna is preserved in the black shale than has yet been obtained in the corresponding beds at Eureka, and a belt of intercalated limestone in the shale similar to that found east of Sugar Loaf at Eureka bears equal evidence of its Devonian age. Here the limestone appears as a lenticular body in the shale, with beds identical in composition both above and below." These statements taken alone are also somewhat ambiguous and it is impossible, out of context, to be absolutely certain whether the "lenticular body" of limestone is in Applegarth Canyon, if so it is certainly a body of limestone wholly within the "argillaceous shale" and, therefore, part of the White Pine Shale as typified by Hague in the White Pine District. If, however, one assumes that the "lens" is in Packer Basin and that the limestone in Applegarth Canyon is a continuous bed, then it may be argued that Hague had modified his conception of the White Pine Shale in Applegarth Canyon and elsewhere in the White Pine District to include the "calcareous shale" and "siliceous limestone". This conclusion may be justified by rigorous analysis of Hague's grammatical construction on page 193, but it is rejected for the following reasons: (1) If Hague included the "siliceous limestone" and "calcareous shale" in Applegarth Canyon within the White Pine Shale as suggested by his phraseology on page 193 of Monograph 20, this is the only place wherein such a correlation is suggested in his writings. Otherwise he is consistent in his use of lithologic terminology and restricts the White Pine Shale of the White Pine District to rocks described as either "argillaceous," "arenaceous," or "bituminous" shale. (2) On page 193 Hague states that the shale above and below the "lenticular body" is of the same composition, but on page 81 the shale layers above and below the limestone with *Chonetes* in Packer Basin are described differently. Thus the "lenticular body" must be the limestone in Applegarth Canyon.

This means that Hague, in 1892, correlated units one through four of his Packer Basin Section in the Eureka District with the White Pine Shale of the type area in the White Pine Mining District. Inasmuch as Nolan *et al.* (1956) have identified the limestone with *Chonetes* in Packer Basin as the Joana Limestone and unit 4 as the Pilot shale, this means that Hague's 1892 correlation is incorrect, according to our persent knowledge of these rocks, because he equates the upper Mississippian shale of the White Pine District with the uppermost Devonian shale, lower Mississippian limestone and upper Mississippian shale of the Eureka District. Furthermore, this miscorrelation has been the source of much confusion regarding the limits of the White Pine Shale, the upper Mississippian shale unit in question.

Lawson (1906) followed Hague's correlations in describing the White Pine Shale in the Robinson (Ely)

District. Lawson (1906 : 296) states, "This shale formation, with its included limestone bed agrees well with the descriptions that have been given by Hague for the White Pine shale of the neighboring White Pine and Diamond Ranges . . . Even the thick bed of limestone in the midst of the shale has its analogue in the White Pine shale of the Eureka and White Pine sections." Lawson refers to Hague's 1892 discussion on pages 192-193, thus making it plain that he is referring to the lens of limestone in Applegarth Canyon and the limestone with *Chonetes* at Packer Basin. Spencer (1917 : 25-26) accepted Lawson and Hague's correlations and assigned formal stratigraphic names to the three units described by Lawson. The lower shale, equivalent to Hague's "calcareous shale" of the White Pine District, was named, "Pilot Shale." The middle limestone, equivalent to Hague's "siliceous limestone", was named, "Joana Limestone," and the upper shale, equivalent to Hague's "argillaceous shale", was named, "Chainman Shale." Thus Lawson (1906) and Spencer (1917) correctly correlate rock units in the Ely District with those of Hague's Packer Basin section near Eureka, but are incorrect in company with Hague, in comparing these sections with the type White Pine Shale in the White Pine Mining District

The Chainman Shale in the Robinson Mining District consists almost entirely of black, fissile shale (Fig. 2). Thus the poorly exposed, thin calcareous siltstone unit is not mentioned by Lawson (1906) or by Spencer (1917). In addition, the relatively thin sandy shale unit is

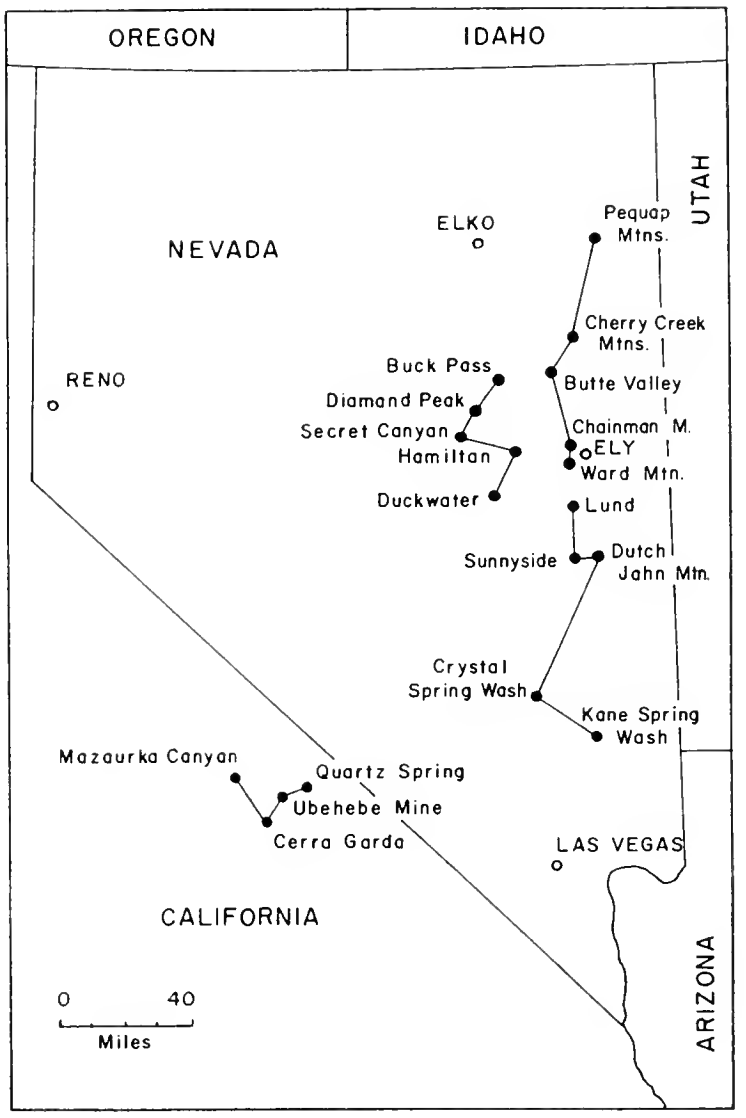

Fig. 1.—Location Map.

only briefly discussed by Spencer (1917) who also points out the absence of the Diamond Peak Quartzite in the mining district.

In 1932 Westgate (Westgate and Knopf, 1932: 19-21) described the sequence at Silverhorn in the Pioche District and at Dutch John Mountain about 40 miles north of Pioche. Here Westgate assigned the detrital rocks between the Lower Mississippian Bristol Pass (Joana or "siliceous") Limestone and the Late Mississippian or Early Pennsylvanian Bailey Spring Limestone to the newly-described Peers Spring Formation and Scotty Wash Quartzite. Although the Scotty Wash Quartzite is analagous to the Diamond Peak Formation, it is of slightly differing composition, is presumably

derived from a different source area, and probably is geographically separated from the Diamond Peak Quartzite (James, 1954). The Peers Spring Formation, however, occupies the same stratigraphic position, includes rocks of the same sort and is presumably geographically continuous with the Chainman Shale as defined by Spencer (1917) and the White Pine Shale in the White Pine Mining District as defined by Hague (1882, 1883, 1892) (Langenheim and Peck, 1960).

Westgate describes the Peers Spring Formation as follows: "The most noticeable type (*of rock*) is a black, dense, fine-grained limestone, much of it gray-white on the weathered surface, very thin bedded, locally almost shale-like in its lamination. Probably a more common facies, though not so often seen in actual outcrop because it is a softer rock, is a brown calcareous shale that effervesces slightly in warm hydrocholoric acid. The formation as a whole weathers easily, so that outcrops are scarce, the surface being covered with fine gray, lavender, or rusty debris. Interbedded in the shale and thin limestones of the lower part of the formation are blue-black limestones, some layers of which are 4 feet thick. These seem to form a transition by intercalation to the underlying Bristol Pass limestone." (Westgate and Knopf, 1932: 20). Re-examination of the type and reference areas (Langenheim and Peck, 1960) has shown that accidents of exposure make outcrops of the calcareous siltstone unit (Fig. 2) most extensive in the Peers Spring area and, as suggested by Westgate (Westgate and Knopf, 1932: 20), give an erroneous impression regarding the formation. Thus, although Westgate's description pertains almost entirely to the calcareous siltstone unit, all three units—calcareous siltstone, black fissile shale, and sandy shale—are present. These relationships are difficult to detect at Peers Spring but are well displayed at Dutch John Mountain (Langenheim and Peck, 1960).

Problems of exposure also led Westgate (Westgate and Knopf, 1932) to misinterpret the basal contact of the Peers Spring Formation at Peers Spring and the Peers Spring-Scotty Wash contact at Dutch John Mountain (Langenheim and Peck, 1960). Lower Mississippian fossils reported from lenses in the basal Peers Spring Formation at Peers Spring are actually from infaulted blocks of Bristol Pass Limestone and the great thickness of Scotty Wash Quartzite reported at Dutch John Mountain appears largely to result from inclusion of talus-covered shale slopes within the quartzite formation (Langenheim and Peck, 1960).

In 1953 the stratigraphic correlation committee of the Eastern Nevada Geological Association (Easton *et al.*, 1953) accepted Hague's (1883) designation of the White Pine Mining District as the type area for the White Pine Shale. The Pilot Shale, Joana Limestone and Chainman Shale, however, were included as members within the White Pine Formation at Ely and Eureka (Easton *et al.*, 1953, fig. 2) and, by implication, within the White Pine Mining District as well. In their column for the Pioche District

(Easton *et al.*, 1953, fig. 2) the Pilot Shale and Joana Limestone (Bristol Pass Limestone) are shown as members of the White Pine Formation, but the Peers Spring Formation is treated separately because, "It is probable that the Peers Spring formation includes the Chainman shale and part of the Diamond Peak formation." (Easton *et al.*, 1953: 149). Thus, Hague's (1892), Lawson's (1906) and Spencer's (1917) miscorrelation of the Eureka and Ely sections with the White Pine Shale of the White Pine District was reinforced. Also, by implication, the type section in the White Pine District was revised to include the "siliceous limestone" and "calcareous shale" previously assigned to the Nevada Formation by Hague (1870, 1892) and King (1878).

McAllister (1952: 22-26) created local formations in dealing with Late Mississippian detrital rocks in the Quartz Spring Area, northern Panamint Range, California. Calcareous siltstone and shale with interbedded limestone is included in the upper part of the Perdido Formation. Black argillaceous shale resting on a *Cravenoceras* biostrome at the top of the Perdido Formation is assigned to the Rest Spring Shale. The upper part of the Rest Spring Shale is silty, includes minor interbeds of quartzite and is succeeded by the Pennsylvanian Tihvipah Limestone. Langenheim and Tischler (1960: 110, fig. 5) have redescribed the Perdido Formation in greater detail and correlated the Upper Perdido Formation with the regional calcareous siltstone. The Rest Spring Shale is correlated with a Chainman Shale concept restricted to the "argillaceous and arenaceous shale" of the White Pine District.

Nolan *et al.* (1956) review the nomenclature of the White Pine Shale in a restudy of the Paleozoic section in the Eureka District. Nolan *et al.* (1956: 54) cite the White Pine Mining district as the type locality of the White Pine Shale. They appear, however, indecisive regarding Hague's conception of the White Pine Shale in the Eureka District. On one hand they state, in reference to the Joana Limestone in the Eureka District, that "although the unit was clearly recognized in a section measured in Packer Basin, southeast of Eureka (Hague, 1892: 81). It is not clear from this reference, however, if Hague intended to include the Joana with the underlying Devonian sedimentary rocks, or with his White Pine Shale." (Nolan, *et al.*, 1956: 54). Elsewhere, they state in regard to the Pilot Shale, "The lowest beds of the White Pine Shale, as defined by Hague (1892: 68-69), differ in lithologic character from the rest of the beds that were assigned to that unit and appear to be equivalent in stratigraphic position and relationships to the Pilot shale of the Ely district (Spencer, 1917: 26)." (Nolan *et al.*, 1956: 52). Although Hague's (1892: 81) discussion of the Packer Basin section regarding assignment of the limestone with *Chonetes* (Joana Limestone), appears ambiguous out of context, his correlation of this section with the Applegarth Canyon section (Hague, 1892: 193) clearly indicates that he placed the limestone with *Chonetes*, and the shale below in the White Pine Shale, as

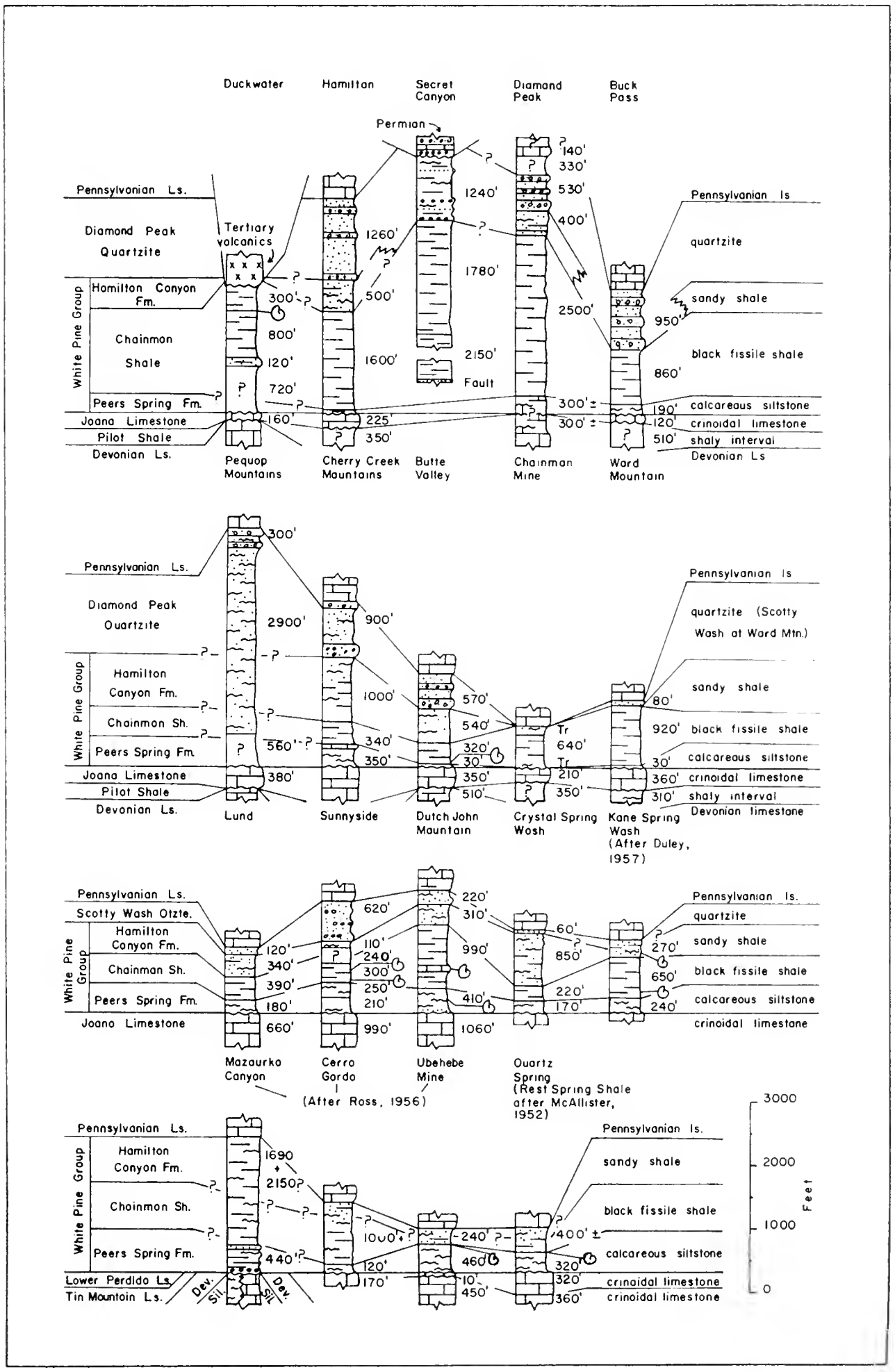

FIG. 2.—Columnar sections of Late Mississippian detrital rocks in the central Great Basin.

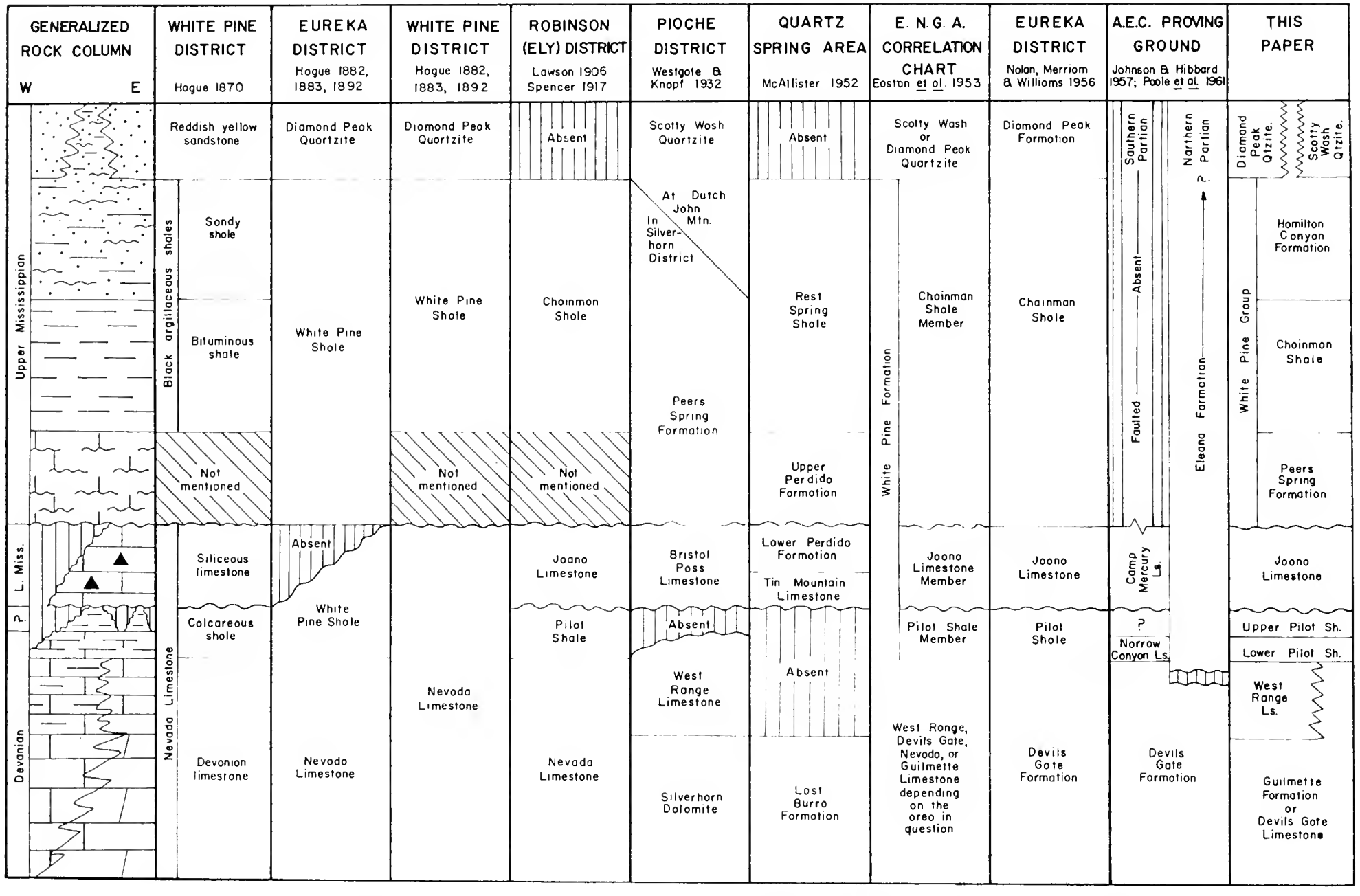

FIG. 3.—Graphic summarization of the nomenclatorial history of the Late Mississippian rocks of the central Great Basin.

he conceived it in the Eureka District.

Nolan *et al.* (1956) further point out that most workers were confused regarding the nature of the White Pine Shale and that many used the name, "White Pine" incorrectly. Therefore, they proposed rejection of the White Pine Shale concept and adopted the Chainman Shale concept for use in the Eureka District, because:

1) Hague's White Pine Shale and Diamond Peak Quartzite were not satisfactory mapping units for their work in the Eureka District. These units show extreme differences in thickness and lithologic character both between and within individual thrust plates.

2) The White Pine Shale has been applied to black shale sequences of excessively wide range as, for example, in the Eureka District where it became necessary to remove the Pilot Shale and Joana Limestone from the unit mapped as White Pine Shale by Hague.

3) Inclusion of the Pilot Shale, Joana Limestone and Chainman Shale as members within the White Pine Formation, as employed by the stratigraphic committee of the Eastern Nevada Geological Association (Easton *et al.*, 1953) "has the advantage of retaining the name, "White Pine" for the dominant black shale sequence, (*but*) does not provide for satisfactory treatment of the thick gradational zone between the black shales and the coarser clastics characteristic of Hague's Diamond Peak." (Nolan, *et al.*, 1956: 57). Nolan *et al.* (1956) solve this problem by separately recognizing the Chainman Shale and Diamond Peak Formation where they can be satisfactorily distinguished and elsewhere referring to the undivided sequence as "Chainman and Diamond Peak Formations undifferentiated."

Johnson and Hibbard (1957: 356-360) introduce another set of local formations in mapping the A. E. C. Proving Grounds. The Narrow Canyon Limestone consists of platy, buff-weathering silty limestone which appears similar to the Lower Pilot Shale of Langenheim (1961) and is tentatively correlated with the Pilot Shale by Johnson and Hibbard (1957: 356). The Camp Mercury Limestone is described as a probable correlative of the Joana and Tin Mountain Limestones, but the Eleana Formation is less readily compared with rocks of other areas. Although the Eleana Formation was not observed in stratigraphic contact with the Camp Mercury Limestone, Johnson and Hibbard (1957) assume it to be stratigraphically above the limestone. The lower part of the Eleana Formation consists of black shale and is compared with the Chainman Shale of the Eureka District as recognized by Nolan *et al.* (1956) (Johnson and Hibbard, 1957). The middle quartzitic portion of the Eleana Formation is tentatively correlated with the Diamond Peak Formation of Noland *et al.* (1956), but no attempt was made to compare the upper, shaly portion of the Eleana Formation to rocks elsewhere (Johnson and Hibbard, 1957). Poole *et al.* (1961) have revised this treatment of the Eleana Formation after discovery of a locality in which the Eleana Formation rests disconformably on Devon-

ian limestone. Thus they correlate the basal Eleana Formation with the Narrow Canyon and Camp Mercury Limestone and approximately equate the remainder of the Eleana Formation with the Chainman Shale, Diamond Peak Formation and, possibly, basal Ely Limestone of the Eureka District (Poole *et al.*, 1961, table 328.2).

Suggested Regional Terminology for the Late Mississippian Rocks of the Central Great Basin

Part of the confusion regarding Late Mississippian stratigraphic nomenclature in the central Great Basin arises from conflicting needs of geologic mapping and those of basin-wide stratigraphic synthesis. Local formational concepts are needed in many localities for efficient mapping within a mountain range or mining district. These local concepts, however, may not coincide with formational units of greatest regional significance. In some instances, growth of knowledge may "overtake" such local concepts and it may be useful either to abandon or revise them to bring them into conformity with regional units having the same local value. The terminology of Johnson and Hibbard (1957) and Poole *et al.* (1961) refers to a set of such presently useful local formational concepts. Spencer's (1917) units at Ely and Westgate's (Westgate and Knopf, 1932) units at Pioche are other examples in which the advance of stratigraphic knowledge has made the need for a local terminology more or less obsolete.

Units for regional synthesis should reflect the distribution of major rock types within the basin because only units such as these are of environmental and paleogeographic significance. In the central Great Basin, the Late Mississippian detrital sequence includes five major rock units of this sort. They are the basal calcareous siltstone unit, the black fissile shale unit, the sandy shale unit and the two geographically distinct quartzitic and conglomeratic units mentioned in the introduction to this paper. Three of these units were recognized by Hague in 1870 as the bituminous and sandy members of the black argillaceous shale and the reddish yellow sandstone. The basal calcareous siltstone unit is thickest in the Pioche District and is the dominant lithologic type described by Westgate (Westgate and Knopf, 1932) in his discussion of the Peers Spring Formation. The black fissile shale unit is widespread throughout the area and constitutes almost all of the Chainman Shale as described by Spencer in the type area. The sandy shale sequence is thickest in the western part of the area but has not been as yet the basis of a separate formational concept. The uppermost quartzitic and conglomeratic sequence includes the Diamond Peak Quartzite. This formation is thickest in the Eureka District and is separated by an area in which quartzite is absent from exposures of the Scotty Wash Quartzite. Distribution of the Scotty Wash Quartzite centers on the Pioche District.

A rational classification for regional synthesis should include all of these units and should also follow priority in definition and naming of stratigraphic concepts. Thus the White Pine Shale, raised to

Group status, is retained for the entire fine-grained detrital sequence and the Scotty Wash Quartzite and Diamond Peak Quartzite concepts are applied to the appropriate, separate coarse-grained rock bodies.

Retention of the White Pine Shale as a Group is justified for the following reasons:

1) Hague's original statements in 1882 and 1883 clearly designate the argillaceous shale of the White Pine Mining District as the basis for this formation concept. His map of 1870 and the more extensive discussions of 1892 establish the type section of the White Pine Shale as including the entire body of fine-grained detrital rock stratigraphically above the "siliceous limestone" and below the Diamond Peak Quartzite.

2) The recommendation of the Eastern Nevada Geological Association Stratigraphic Committee (Easton *et al.*, 1953) that the White Pine Shale be treated as comprising the Pilot Shale, Joana Limestone and Chainman Shale is rejected as based on miscorrelations by Hague (1892), Lawson (1906) and Spencer (1917) of rocks at Eureka and Ely with the type section of the White Pine Shale in the White Pine District.

3) The recommendation of Nolan *et al.* (1956) that the name "White Pine" be suppressed and the name, "Chainman" be applied to the upper shale is rejected because the Chainman Shale of Spencer (1917) is a junior synonym of the White Pine Shale of Hague (1882, 1883, 1892) in the type area. The arguments of Nolan *et al.* (1956) to the effect that Hague's formational concept does not satisfactorily serve the needs of geologic mapping in the Eureka District and elsewhere are considered in large part equally applicable to use of the same formational concept under a junior name. These arguments are valid in respect to the needs of local mapping and, it may be pointed out, have been met by Nolan *et al.* (1956) through recognition of a local, undifferentiated Chainman and Diamond Peak unit.

4) Finally, it has been widely argued that the Chainman Shale concept is untainted by past confusion regarding its application and that current usage favors use of the Chainman concept and name. This argument is rejected because it is felt that the White Pine concept of Hague is in fact clearly recognizable and that differences of opinion regarding its application are capable of resolution by comparison of the rocks in question with those of the type locality. In fact, the White Pine Mining District section, selected as a reference section by Humphrey (1960), is superior to the Chainman type section in that it is better exposed, less metamorphosed and deformed, and has a better representation of the three recognized lithologic subunits within the sequence. The appeal to general usage is rejected as not being capable of objective resolution.

The three lithologic units within the White Pine Group now require definition and designation of type or reference sections. It is suggested that the Peers Spring Formation concept be restricted to the basal calcareous siltstone unit with units 2-5 in the section south of Dutch John Mountain (Langenheim and Peck, 1960: 541, fig. 3) designated

as a reference or type section for the restricted formation concept. This seems appropriate inasmuch as the calcareous siltstone is best developed in this area and Westgate's (Westgate and Knopf, 1932) original description is actually almost entirely a description of the calcareous siltstone assemblage. Further, it is recommended that the Chainman Shale concept be restricted to the black fissile shale unit with section V (Langenheim *et al.*, 1960: 149, 151, fig. 1) on the west side of Ward Mountain south of Ely designated as a reference section for the restricted formational concept. This seems appropriate inasmuch as Spencer's concept enjoys priority and the section in the Ely area consists almost entirely of the black fissile shale unit.

Inasmuch as the uppermost sandy shale unit is not presently recognized as a formal stratigraphic unit it is proposed that the unit be referred to as the Hamilton Canyon Formation. The type section is designated as the appropriate portion of the White Pine Shale section shown for the White Pine District in Figure 2. This section was measured along a traverse starting at the White Pine-Joana contact on the north side of the water gap through the Joana Limestone in the NE ¼, sec. 31, T. 17 N., R.58 E., Illipah Quadrangle, White Pine County, Nevada. The traverse proceeds eastward through cover to the end of a spur in the Chainman Shale Formation and thence continues roughly along the crest of the spur to the base of the Ely Limestone near the Hamilton-Illipah Road. The base of the Hamilton Canyon Formation is well-marked by a soil and vegetation change at the top of the black, fissile shale to open grassland with scattered outcrops of silty shale and fine-grained sandstone. The upper contact is taken at the base of the lowest significant sandstone layer. The thickness and general character of the Hamilton Canyon Formation in its type locality and elsewhere in eastern Nevada are shown on Figure 2.

The Diamond Peak Quartzite and Scotty Wash Quartzite concepts are retained for the dominantly quartzitic and conglomeratic units spreading eastward from the Diamond Range and centering on the Pioche District respectively.

Acknowledgments

Special thanks are due Philip Playford for his energetic defense of the Eastern Nevada Geological Association classification in a prolonged running debate on the questions discussed herein. J. H. Langenheim and L. J. Stensaas served as field assistants and the Department of Paleontology and the Faculty Research Fund of the University of California at Berkeley supplied field expenses for the field studies upon which this work ultimately rests. H. R. Wanless kindly read and criticized the manuscript. Finally the author begs forgiveness for any excessive zeal in pressing his argument and invites reply in the same spirit.

Literature Cited

Duley, D. H. 1957. Mississippian Stratigraphy of the Meadow Va'ley and Arrow Canyon Ranges, Southeastern Nevada. Unpub. M. A. Thesis, Dept. Paleontology, University California, Berkeley, 103 pp., 3 pls., 7 figs.

EASTON, W. H., *et al.* 1953. Revision of stratigraphic units in Great Basin. Bull. Amer. Assoc. Petrol. Geol., 37(1): 143-151, 2 figs.

HAGUE, ARNOLD. 1870. Geology of the White Pine Mining District, U.S. Geol. Exploration Fortieth Parallel (King), 3: 409-421, atlas sheet 14.

————. 1882. Report of Mr. Arnold Hague, 2nd Ann. Rept. U.S. Geol. Survey, 1880-81: 21-35.

————. 1883. Abstract of report on geology of the Eureka District, Nevada. 3rd Ann. Rept. U.S. Geol. Survey, 1881-82: 237-290, pls. 24-25.

————. 1892. Geology of the Eureka District, Nevada. U.S. Geol. Survey Mon. 20, xvii + 499 pp., 8 pls., 9 figs., 13 Atlas Sheets.

————, and S. F. EMMONS. 1877. Descriptive Geology. U.S. Geol. Exploration Fortieth Parallel (King), xiii + 890 pp., 26 pls.

HUMPHREY, F. L. 1960. Geology of the White Pine Mining District. Nevada Bur. Mines Bull. 57, xiv + 119 pp., 2 pls., 25 figs.

JAMES, J. W. 1954. Upper Mississippian-Lower Pennsylvanian rocks, southern Egan Range, Nevada (Abstract). Bull. Geol. Soc. Amer., 65(12) (2): 1268.

JOHNSON, M. S. and D. E. HIBBARD. 1957. Geology of the Atomic Energy Proving Grounds Area, Nevada. U.S. Geol. Survey Bull. 1021-K:333-384.

KING, CLARENCE. 1876. Paleozoic subdivisions on the 40th Parallel. Amer. Jour. Sci., 111: 475-482.

————. 1878. Systematic Geology. U.S. Geol. Exploration Fortieth Parallel (King), xii + 803 pp., 23 pls.

————. 1880. First Annual Report of the U.S. Geological Survey, 62 pp.

LANGENHEIM, R. L., JR. 1956a. Lower Mississippian stratigraphic units in southern Nevada (Abstract). Bull. Geol. Soc. Amer., 67(12)(2):1773.

————. 1956b. Mississippian stratigraphy in eastern Nevada (Abstract). Bull. Geol. Soc. Amer., 67(12) (2): 1714.

————-. 1960. Early and Middle Mississippian stratigraphy of the Ely Area. Guidebook Geol. East-central Nevada, Intermtn. Assoc. Petrol. Geol., 11th Ann. Field Conf., pp. 72-80, 6 figs.

————. 1961. The Pilot Shale, the West Range Limestone, and the Devonian-Mississippian boundary in Eastern Nevada. Trans. Illinois Acad. Sci., 53(3-4): 122-131, 3 figs.

————, *et al.* 1960. Preliminary report on the geology of the Ely No. 3 Quadrangle, White Pine County, Nevada. Guidebook Geol. East-central Nevada, Intermtn. Assoc. Petrol. Geol., 11th Ann. Field Conf., pp. 148-156, 3 figs.

———— and J. H. PECK. 1960. La Formation de Peers Spring dans le Pioche District, Nevada, Cahiers Geol., 56:537-548, 3 figs.

———— and HERBERT TISCHLER. 1960. Mississippian and Devonian paleontology and stratigraphy, Quartz Spring Area, Inyo County, California. Univ. Calif. Pub. Geol. Sci., 38(2): 89-150, pls. 14-15, 18 figs.

LAWSON, A. C. 1906. The copper deposits of the Robinson Mining District, Nevada. Univ. Calif. Publ. Bull. Geol., 4(14): 287-357.

MCALLISTER, J. F. 1952. Rocks and structure of the Quartz Spring Area, Northern Panamint Range, California. Calif. Div. Mines Spec. Rept., Vol. 25, 38 pp., 3 pls., 13 figs.

NOLAN, T. B., *et al.* 1956. The stratigraphic section in the vicinity of Eureka, Nevada. U. S. Geol. Survey Prof. Paper 276, 77 pp., 2 pls., 2 figs.

POOLE, F. G., *et al.* 1961. Eleana Formation of Nevada Test Site and vicinity, Nye County, Nevada. U. S. Geol. Survey Prof. Paper 424-D:104-111, 2 figs., 2 tables.

ROSS, W. A. 1956. Mississippian rocks in eastern California and adjacent Nevada (Abstract). Bull. Geol. Soc. Amer., 67(12) (2): 1729.

SPENCER, A. C. 1917. The geology and ore deposits of Ely, Nevada. U. S. Geol. Survey Prof. Paper 96, 189 pp., 4 figs., 15 pls.

WESTGATE, L. G. and ADOLPH KNOPF. 1932. Geology and ore deposits of the Pioche District, Nevada. U. S. Geol. Survey Prof. Paper 171, 79 pp., 8 pls., 13 figs.

WILMARTH, M. G. 1938. Lexicon of geologic names of the United States (including Alaska), Part 2, M-Z. U. S. Geol. Survey Bull., 896(2): 1245-2396.

GROUND WATER GEOLOGY OF THE DEKALB AND SYCAMORE QUADRANGLES

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The DeKalb and Sycamore quadrangles lie principally in central DeKalb county. Their east and west margins extend into the western tier of Kane county townships and the eastern tiers of Ogle and Lee counties townships. Both Leighton (1958) and Frye (1960) described the surface of the study area as almost entirely covered by Tazewell' glacial drift materials, with the exception of the very narrow flood plains of the streams. The surface of Tazewell drift is covered almost entirely by Peorian loess and silts. Locally the loess and silt covers Sangamon soil and Illinoian glacial drift.

This writer (1936) previously described the glacial surfaces. They consist of two morainal ridges which cross the area in a northeast-southwest direction. These ridges belong to the general Bloomington morainic system. The western or outer ridge covers the west half of the DeKalb quadrangle. This ridge is the northern limit of the Bloomington moraine. The inner ridge or Arlington moraine covers the southeast corner of the DeKalb quadrangle and much of the Sycamore quadrangles.

The study area (Figure 1) varies in topography from flat to slightly rolling. The streams all flow in shallow valleys. The relief is due largely to irregular deposition of glacial materials super-imposed upon bedrock relief. The moraines are characterized by an irregularly rounded, undulating topography. These moraines vary in width from 3 to 6 miles.

The southeast part of the Sycamore quadrangle has a gradual surface which slopes toward the Fox River valley. This area is drained into the Illinois River. The remaining surface is drained to the north through the south branch of the Kishwaukee river, which empties into the Rock river south of Rockford. A small area in the northwest part of the DeKalb quadrangle drains to the northwest in the east branch of Killbuck Creek.

The streams have done very little cutting into the glacial blanket since the retreat of the Wisconsin ice. Stream-cuts seldom occur with depth greater than 15′ to 20′. This slight amount of post-glacial erosion has done very little to change the glacial topography except in the immediate valleys of the streams. Narrow alluvial flood plains occur irregularly along the stream banks only a few feet above the average water level.

Procedure

This is a study of the glacial drift, bed-rock topography, and groundwater geology in the DeKalb and Sycamore quadrangles. Data are secured largely from drilled-well records located in and near the study

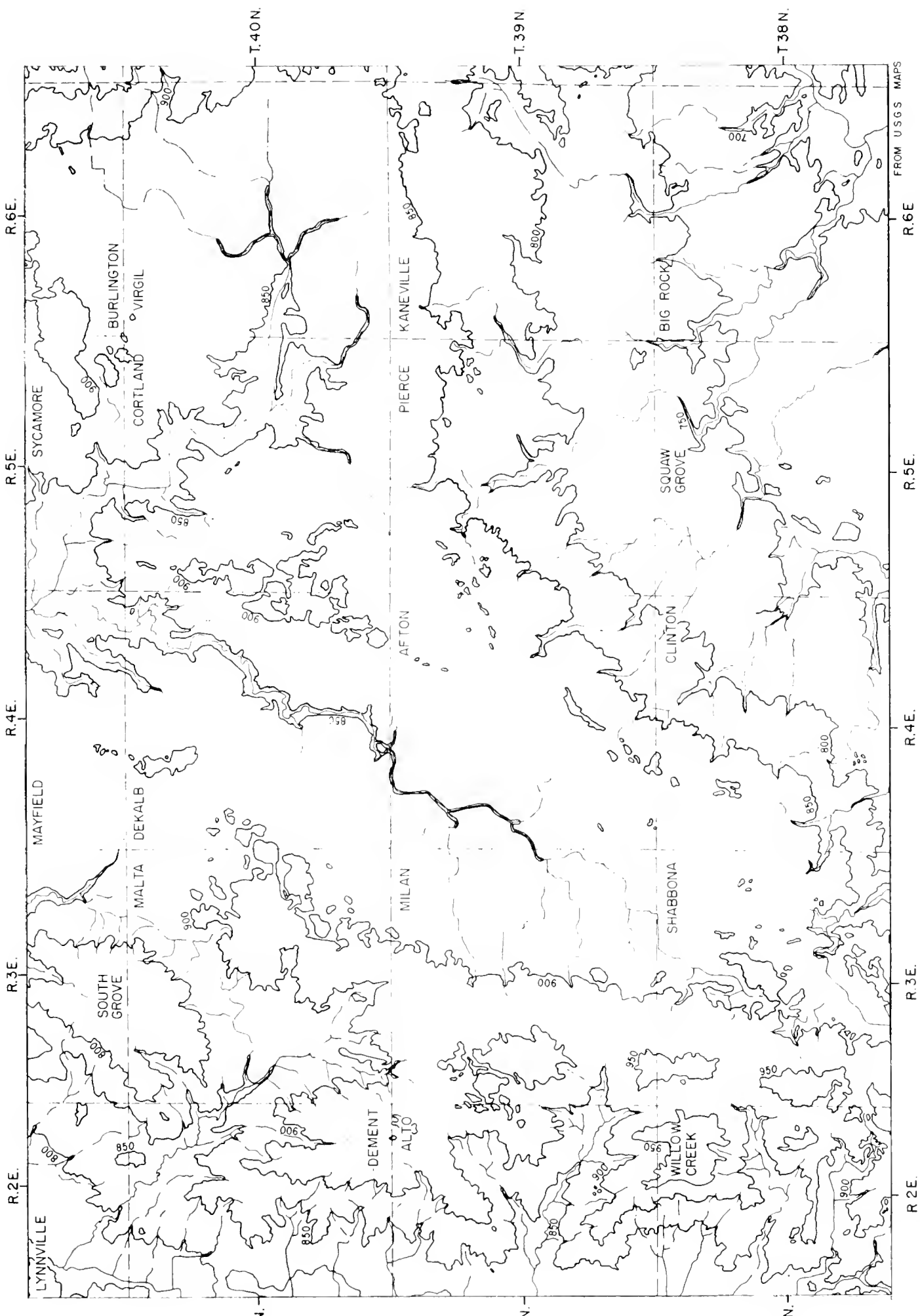

FIG. 1.—Topographic Map of DeKalb and Sycamore Quadrangles. One inch equals 5 miles; contour interval is 50 feet. Datum is mean sea level.

area. The United States Geological Survey topographic maps for the DeKalb and Sycamore quadrangles are used as a base upon which to chart the well log data. A large portion of the well logs are secured directly from well-drillers' records. 25 well records are secured from the files of the Illinois State Geological Survey well record file library.

All well records studied include the location of the well, the owner's name, the description and thickness of the rock formations through which the well penetrated, and ground water geology data made available through test pumping of the wells. These data include the piezometric levels and pump down capacity of the water in the aquifer strata tapped by the well. All well locations are charted on topographic maps, which show the following: altitude of well's surface, bedrock surface levels, and thickness of rock strata penetrated by each well. A bedrock surface contour map, and an areal geology map are made from these data. Since some wells did not penetrate the glacial drift to the bedrock surface, data from the deepest of these wells are used for their negative value in determining the elevation of the bedrock surface.

Glacial Drift Cover

The field data showing the glacial drift cover came from a total of 1100 well records. More than 930 of these well logs are located in the DeKalb and Sycamore quadrangles, while the remaining 150 well logs are located marginally outside the area. There are 542 wells which penetrate bedrock and 338 wells which end in the glacial drift.

The initial study of this area was started in 1936 by this writer. The present study includes subsequent well log data. The well log data collected have made possible the charting of a bedrock surface map. These map data show drift thickness and buried bedrock surface information. The average thickness of the glacial drift is about 150′. Its greatest thickness is more than 350′. The minimum thickness is found in Cortland township. Here its minimum thickness is 15′. Loess and silt covers the drift over the entire area except in present stream channel and flood plain areas with thicknesses of 1.5′ to 2.7′.

Buried Bedrock Surface

Bretz (1923), Ekblaw (1938), Foster (1956), Hackett (1960), and Horbert (1946), have separately reported that the buried bedrock surface in northern Illinois consists of deep valleys separated by high ridges. Buried bedrock river-channels and their directions of slope were charted on Figure 2. Locally it was difficult to decide the direction-of-flow and the elevation of divides for some minor preglacial tributaries due to a lack of well log data. For example, in the southwest part of the DeKalb quadrangle in Willow Creek township, section 14, a well penetrates glacial drift to an elevation of 552′. Similarly, levels of 600′, 610′, 632′, and 640′ have been reached without encountering bedrock in section 23, 10, 10 and 2, respectively. In addition, in Shabbona township, section 6, a well reached a 580′ level in drift and in

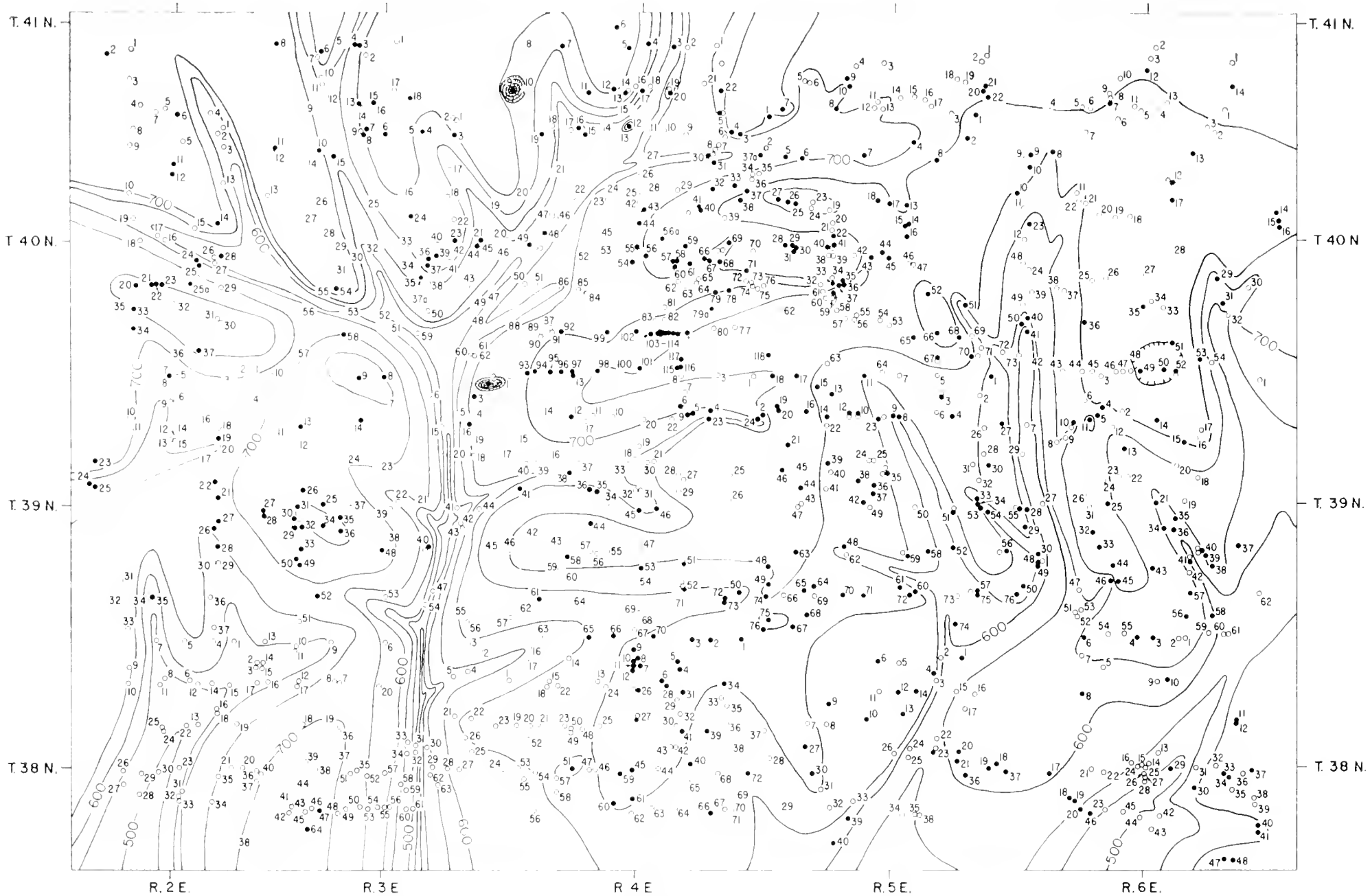

FIG. 2.—Well Location and Bedrock Surface of DeKalb and Sycamore Quadrangles. Bedrock surface contour interval is 50 ft. Circles represent wells ending in drift; solid dots represent wells ending in bedrock. One inch equals 5 miles.

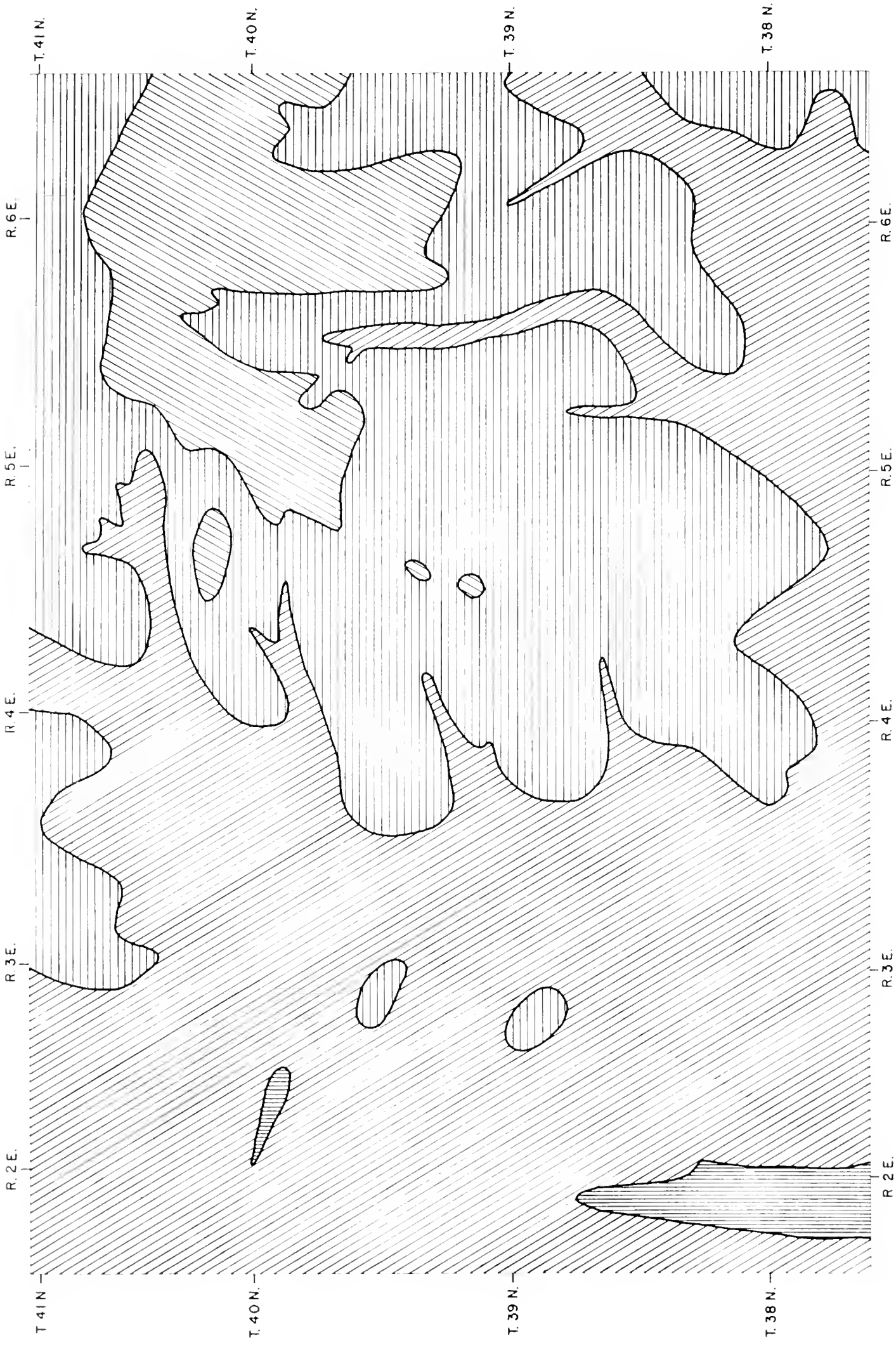

FIG. 3.—Areal Geology of DeKalb and Sycamore Quadrangles. One inch equals 5 miles. Vertical hatching represents St. Peter Sandstone: horizontal hatching represents Maquoketa Shale: right oblique hatching represents Galena-Platteville Dolomite. Niagaran Limestone; left oblique hatching repre

Alto township, section 36, a well reached a 630′ level. Since wells have entered rock at levels from 700′ to 750′ in west central Shabbona, south central Alto, and southwest Milan townships, it is postulated that a short tributary here led into the Old Rock River instead of entering the Shabbona tributary. This conclusion was made because the stream valley should logically face in that direction at that location in order to be attached to the Old Rock River Valley. This valley was reported by Knappen and others (1926) to be located immediately to the west of this location.

Two wells in Alto township, section 12, enter rock at 640′ and in section 12 at 690′. These wells are surrounded by higher bedrock levels, consequently a tributary probably entered the Old Rock River to the west.

Well log records indicate two southeast facing valleys to the west and northwest of Creston. These two valleys probably joined near the north and west edges of the quadrangle due to the proximity of the Old Rock River only two or three miles west of this quadrangle. The presence of a steep stratigraphic dip in this part of the quadrangle is a reason for expecting steep gradient valleys which face east. Also, a bedrock ridge extends from south to north across the DeKalb quadrangle, west of the Shabbona tributary.

Most of the buried bedrock topography of the DeKalb and Sycamore quadrangles is determined by two dendritic streams valleys which flow south across the two quadrangles and south west just beyond the south edge of the area. One of these streams is located in the DeKalb and the other in the Sycamore quadrangle. The west and east tributaries will be called the Shabbona and Hinkley tributaries respectively.

The Shabbona tributary valley extends lengthwise through the center of the DeKalb quadrangle, extending south out of the quadrangle near Shabbona. It has a gradient of 3′ to 5′ per channel mile; and its lowest level is less than 500′ above sea level. This channel floor lies near the bottom contact of the Galena-Platteville with older rocks. Its drainage divide to the west has elevations of 750′ in the northwest part and 700′ in the southwest part of the quadrangle. The drainage divide to the east of this valley attains elevations of more than 800′ to the northeast and 700′ to the southeast.

The Hinkley bedrock valley is located in the south and central parts of the Sycamore quadrangle. This stream has two main branches, one flowing south from the center of the quadrangle and the other flowing southwest along the south edge of the quadrangle. These two branches will be called the Maple Park and the Big Rock branches respectively. The pattern of the Maple Park and the Big Rock branches indicates that they join to the south of the Sycamore quadrangle. These two streams have average gradients near 5′ per mile in their lower courses; their lowest levels are 450′ for the Maple Park branch and 400′ for the Big Rock branch. Their drainage divides vary in altitude from more than 800′ above sea level in the north to 650′ in the south.

The buried bedrock topography of these two quadrangles was formed by pre-glacial streams which eroded rock strata with differing hardnesses. The pre-glacial Rock river, located near the west edge of this region, may have caused the high gradients of this region's pre-glacial drainage channels. The DeKalb quadrangle's western half has its bedrock topography eroded into the Galena formation, resulting in the formation of its flat divides and abrupt valley walls. Two erosional remnants of the soft lower Maquoketa formation occur in parts of Malta and Milan townships. The middle horizon of the Maquoketa formation dominates the east side of the sloping valley in the east half of the DeKalb quadrangle. This Maquoketa-covering of shaly dolomite is very thin. It is immediately underlain by the top of the Galena dolomite formation. Along the extreme east edge of the DeKalb quadrangle, the more resistant middle horizon of the Maquoketa formation, occupies the steep preglacial valley wall. The western half of the Sycamore quadrangle contains the Niagaran limestone which caps the softer upper portion of the Maquoketa formation. This resistant dolomite cap-rock is located principally in Cortland township, and it extends into the northwest part of Pierce township. Relatively steep slopes border this cap-rock. These slopes extend downward through the resistant middle Maquoketa. Four wells (Figure 2) located in the northeast portion of the DeKalb quadrangle may have been drilled into solution cavities or sink holes which were formed by glacial waters dissolving the dolomite of the middle Maquoketa. This resistant rock horizon is located at the 750′ level in the north and near the 700′ level in the south portion of the quadrangle.

The eastern half of the Sycamore quadrangle has bedrock surfaces capped largely by 25′ to 30′ of Niagaran limestone. The streams which cut through this Niagaran capping to the south and west formed steep valleys. One valley south of Maple Park has a crest to crest width of 3 miles and a depth of more than 150′.

Pre-Glacial Drainage Relations

This area has a buried bedrock topography which has been reported by Horbert (1950) to be in accord with the presence of the pre-glacial Rock river, located west of this area. This buried Rock river channel-floor lies at an elevation near 400′, while the buried stream channels of the study area have average levels of less than 500′ for both the Shabbona and Hinckley tributaries. Assuming that they enter the channel of the buried Rock river some miles to the south and slightly west, this difference in level would be expected. The tendency of these tributary streams to parallel the pre-glacial Rock river channel may have resulted from the influence of stratigraphic uplift associated with the sandwich fault which is known to occur immediately to the west of the study area in Ogle County.

Pre-Glacial Areal Geology

A pre-glacial areal geology map was constructed for the study area. Figure 3 was constructed from data

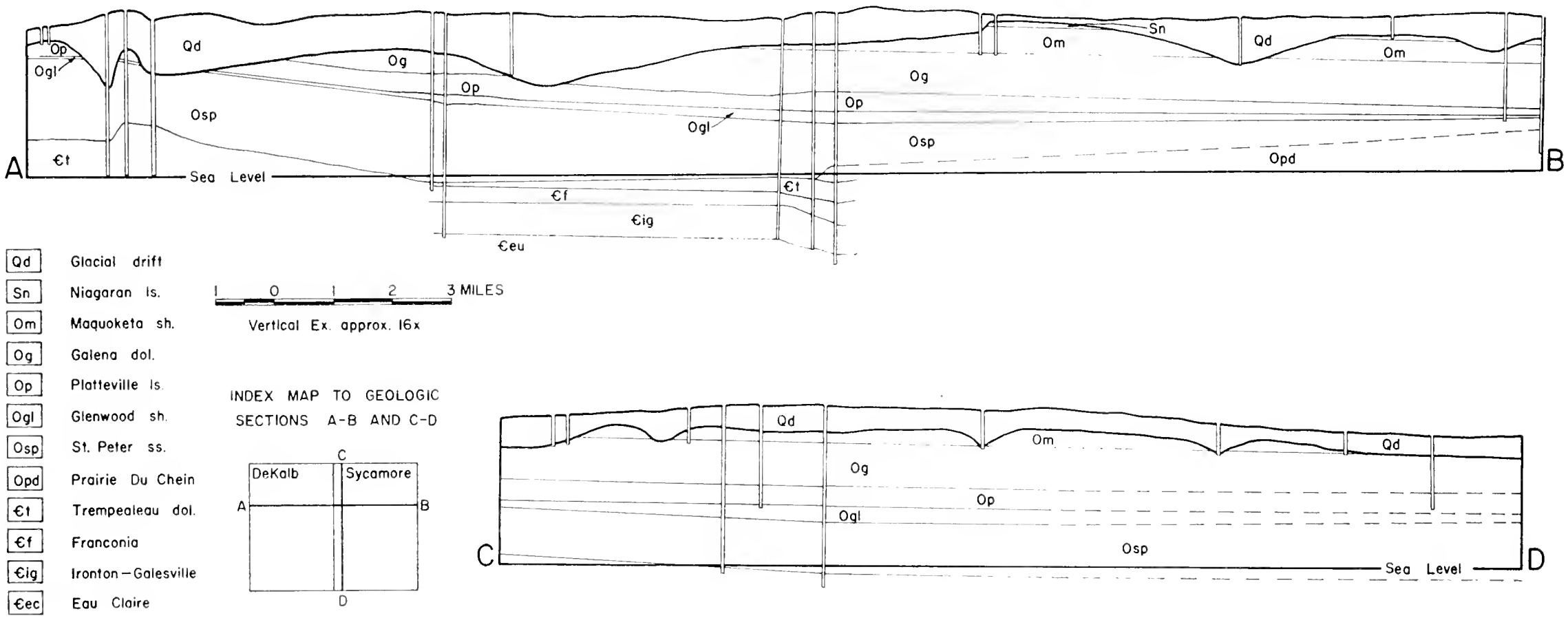

FIG. 4.—Geologic Sections A-B and C-D.

supplied largely by 542 bedrock well records. The Shabbona tributary stream, flowing from north to south through the center of the DeKalb quadrangle, follows closely along the bedrock surface boundary between the Galena and the Maquoketa formations. The Galena formation lies west and the Maquoketa formation lies east of this buried outcrop contact line. Long tongues of the Galena dolomite are exposed in the lower portions of the stream valleys in the south and the central portions of the Sycamore quadrangle. Most of the east half of the DeKalb quadrangle and the west half of the Sycamore quadrangle have Maquoketa rock comprising the bedrock surface; one exception is the long narrow cap rock of Niagaran limestone in Cortland and Pierce townships. Most of the northeast one-third of the Sycamore quadrangle is capped with a very thin remnant of the Niagaran formation, while the southeast corner of the quadrangle has the valley slopes comprised of the Maquoketa and Galena formations.

Since, the pre-glacial surface distribution of rock formations are determined by well records, the question always exists about the extent of these strata between wells. To determine this extent, the bedrock surface contour map and two structural sections were employed. The main areas of rock were fairly easily determined. Certain localities offered problems. For example: the patches of the Maquoketa formation, shown west of the Shabbona tributary stream as capping the upland flats of the Galena dolomite ridge, were suggested by well records numbers 8, 9, 34, and 35 in sections 20, 21, 4, and 5, Milan township. The extent of the formation was postulated in part by widely scattered deep well records and by using known dip slope values and the bedrock surface contour map. The line of contact between the Maquoketa and the Galena formations in the southeast part of the DeKalb quadrangle and the southwest part of the Sycamore quadrangle is derived largely from known stratiographic dip values, and bedrock surface contours.

The arm of Niagaran limestone shown in Cortland township has its presence established by well records numbers 16, 17, 19, 20, and 46 in sections 5, 6, 7, and 18, Pierce township. The areal extent of the formation is determined by widely separated deep well records and upon calculated structure and bedrock contours for the area.

One well record number 28 in section 23, Creston township, indicates that the floor of the pre-glacial valley may be in St. Peter sandstone. Due to the steep east dip of the formation at this location and the probably steep gradient of the pre-glacial stream, it is difficult to determine the bedrock surface extent of this formation. However it has been postulated to lie in a very narrow strip in the bed of this valley as well as in the floor of the pre-glacial valley located in Willows Creek township.

Rock Formations

The nature and extent of rock formations has been determined by using data from about 60 deep well

logs (Table 1). These wells vary in depth from more than 3,000′ to 500′. A few wells, located outside the area, are included in this group where deep well records are not available within the region. A few well logs have been selected which show the lithologic nature of the rock formations in widely separated areas. A few of the deepest wells furnish most of the correlating stratigraphic data. A deep well located in Sycamore township, section 35, SW¼, NW¼, SE¼ was drilled to a depth of 3105′. This well penetrates (Cambrian) sediments with a total thickness of 2080′. These Cambrian strata include: upward; the Mt. Simon sandstone formation with a 1380′ thickness, Eau Claire with 420′, Ironton-Galesville with 145′, Franconia with 80′, and Trempealeau with 55′. These Cambrian formations were practically all sandstone with the exception of the Trempealeau, which was largely cherty dolomite.

Other deep well records show several Ordovician rock formations. The Prairie du Chien formation varies in thickness from 55′ to more than 80′. An unconformity occurs at the top of this formation. The St. Peter sandstone rests upon the eroded surface of the lower formations. This formation varies in thickness from as much as 330′ at Creston to 80′ at Elburn. The Glenwood formation at the top of the St. Peter, varies in thickness from 95′ in the west part of the area to 55′ in the east. The Platteville and Galena formations are considered together in this discussion. They are variable in thickness throughout this area due to pre-glacial erosion, with an original average thickness of 345′. In a few places, the Maquoketa formation is shown to possess considerable thickness. This thickness in the east portion of the area is 127′. The lower 35′ of the Maquoketa formation consists of a soft black shale, interbedded with dolomite, the middle 37′ is fairly compact dolomite, while the upper 35′ of the formation is composed of calcareous shaly dolomite.

A very thin capping of Niagaran limestone (Silurian) is found in the Sycamore quadrangle. This compact dark gray dolomite varies in thickness from 15′ in the western portions to 25′ in the eastern portion of this quadrangle.

Structural Geology and Sections A-B and C-D

Section A-B crosses the area along an east-west line at latitude 45 degrees, 55 minutes (Figure 4). Deep well records at Creston, Malta, DeKalb, Cortland, Maple Park, and Elburn are used in deriving the section. In general, the section was constructed without difficulty. Some questions of well log interpretation arose. For example: well logs at Malta, Creston, and Elburn did not recognize the Glenwood formation; however, the description of the strata in the log led the writer to give the formation, the thickness indicated on the section. The lithologic nature of the Maquoketa is very dolomitic.

Section C-D is located along a north-south line across the area on west longitude 88 degrees 44 minutes (Figure 4). This longitudinal line crosses the north portion of the study area. The structural data of

section C-D is based upon deep well logs which are located largely in the north portion of the section.

Two sections have been made to show the salient features of structure. Section on line A-B crosses the area on a line through Creston, Malta, DeKalb, Cortland, Maple Park, and Elburn. Section on line C-D crosses the area on a line through DeKalb to one mile east of Waterman.

In general, the strata have a dip slope to the southeast. These stratigraphic dip values have been determined by the Maquoketa-Galena strata contact levels. However, dip-slope values have been measured in east-west and north-south directions. The average stratigraphic dip of the formations from Malta to Elburn, an east-west distance of about 20 miles, is from 7′ to 10′ per mile. In contrast to this value, the strata dip from Creston to Malta, an east-west distance of 5 miles, averages 60′ per mile. The direction of dip in this section is to the east. From north to south along the west edge of the DeKalb quadrangle, these strata dip to the south at 10′ per mile over a distance of more than 17 miles. On a line parallel to the above, but along the west edge of the Sycamore quadrangle, the average southerly stratigraphic dip is about 4′ per mile. Along the east edge of the Sycamore quadrangle the average dip is 2.5′ per mile the south. From the northwest corner of the area to the southeast corner, a distance of above 40 miles, the stratigraphic contact level (true dip) drops 560′. This dip direction indicates an average true dip of 14′ per mile. The local true dip values are greatest along the northwest edge of the area and less steep to the southeast. The true average stratigraphic dip in the southeast portion of the area is 9′ per mile.

Ground Water and Aquifer Strata

594 of the wells take water from the glacial drift. 338 wells take water from various bedrock aquifers. A majority of the wells which pump water from bedrock aquifers are located in the population centers of the area. The wells which pump water from the glacial drift formation are widely scattered over the entire area.

Wells ending in the glacial drift varied in depth from place to place. In the area from Creston to south of Lee, many of these glacial drift wells are 200′ to 350′ deep. In the vicinity of Steward and west of Lee, many of the glacial drift wells are driven wells penetrating to depths of 10′ to 30′. Such shallow driven wells also occur northwest of Creston to the northwest corner of the quadrangle. Glacial drift wells in the vicinity of Waterman are near 130′ to 140′ in depth, giving satisfactory amounts of water. Wells near Hinkley vary in depth from 60′ to 80′. Wells north and east of Malta and west and north of DeKalb which do not penetrate bedrock, have depths of 80′, 120′, and 160′. A good share of these wells are no deeper than 80′ with small to average quantities of water for farm uses. Wells taking water from the bedrock formations usually penetrate the overlying strata until one of the following aquifer strata is

TABLE 1.—Well Log Data for 60 Drilled Well Records Which Penetrate Bedrock Formations.

Township	Well Location	Surface Elevation	Bedrock Surface Elevation	Top of Rock Formation	Bottom of Well
Willow Creek	T.38N., R.2E., (1-38) 38 drift wells, 0 bedrock wells.				
Shabbona	T.38N., R.3E., (1-64) 62 drift wells, 2 bedrock wells.				
Clinton	T.38N., R.4E., (1-72) 46 drift wells, 26 bedrock wells.				
Squaw Grove	T.38N., R.4E., (1-40) 21 drift wells, 19 bedrock wells.				
Big Rock	T.38N., R.6E., (1-48) 27 drift wells, 21 bedrock wells.				
10.	S12, SW, NE, SW	710	640 shale	510 limestone	505
11.	S12, SW, SW, SC	700	630 shale	580 limestone	470
12.	S13, SE, NW, SE	735	635 limestone	555 limestone	555
37a.	S24, NE, NW, NE	735	627 limestone	395 limestone	395
47.	S35, NE, NE, NE	700	640 shale	600 limestone	600
48.	S34, SW, SE, SE	700	630 shale	470 limestone	470
Alto	T.39N., R.2E., (1-37) 27 drift wells, 10 bedrock wells.				
Milan	T.39N., R.3E., (1-57) 33 drift wells, 24 bedrock wells.				
2.	S1, NW, NE, SW	880	472 shale	430 limsetone	410
40.	S23, SW, SW, SW	885	484 limestone	400 sandstone	400
Afton	T.39N., R.4E., (1-76) 48 drift wells, 28 bedrock wells.				
61.	S31, NE, NW, NW	880	665 shale	655 limestone	285
Pierce	T.39N., R.5E., (1-76) 24 drift wells, 52 bedrock wells.				

TABLE 1.—Continued.

Township	Well Location	Surface Elevation	Bedrock Surface Elevation	Top of Rock Formation	Bottom of Well
4.	S2, SW, SE, SW	880	712 shale	645 limestone	587
10.	S4, SE, SW, SW	870	710 shale	685 limestone	685
12.	S5, SE, SE, SE	890	711 shale	625 limestone	590
27.	S12, NW, NE, NE	870	660 shale	620 limestone	568
30.	S13, NW, NW, NE	850	686 shale	624 limestone	624
33.	S14, SE, SE, NE	810	646 shale	553 limestone	553
53.	S24, NW, NW, NW	810	664 shale	600 limestone	600
58.	S27, NE, NE, NE	800	660 shale	625 limestone	575
74.	S35, SE, NW, NW	770	613 shale	455 limestone 280 St. Peter sandstone	240
Kaneville	T.39N., R.6E., (1-62) 31 drift wells, 31 bedrock wells.				
4.	S5, SE, SE, SE	860	725 shale	685 limestone	580
			Glenwood shale	655	
			Prairie du Chien dolomite	580	
36.	S22, NE, SW, SW	800	675	635 limestone 615 shale 575 limestone	575
38.	S26, NE, SW, SW	780	655 limestone	640 shale 520 limestone	520
48.	S30, NW, NE, NW	790	670 shale	550 limestone	526
57.	S35, NW, NW, NW	770	680 limestone	668 shale 485 limestone	485
Dement	T.40N., R.2E., (1-38) 24 drift wells, 14 bedrock wells.				
24.	S23, NW, SE, SE	910	730 shale	660 limestone	325
			St. Peter sandstone	325	
25a.	S23, SW, SE, NE	925	675 shale	510 limestone	185

TABLE 1.—Continued.

Township	Well Location	Surface Elevation	Bedrock Surface Elevation	Top of Rock Formation	Bottom of Well
Malta	T.40N., R.3E., (1-62) 47 drift wells, 15 bedrock wells.				
37a.	S22, SE, SE, NW	890	655 limestone	655 Galena Platteville	—363
			St. Peter sandstone	460	
			Trempeleau dolomite	20	
			Franconian dolomite	5	
			Ironton & Galesville sandstone	—85	
			Eau claire sandstone	—255	
39.	S23, NW, SW, NE	920	675 limestone	420 St. Peter sandstone	—300
			Trempeleau & Franconian dolomite	100	
			Ironton & Galesville sandstone	—300	
39a.	S23, SW, NW, NW	900	685 limestone	400 sandstone —100 limestone	—100
DeKalb	T.40N., R.4E., (1-118) 59 drift wells, 59 bedrock wells.				
12.	S4, NW, SW, NW	870	700 shale	687 limestone	665
19.	S6, SE, NW, NE	860	680 limestone	435 sandstone	405
37.	S12, SE, SW, NW	880	730 shale	655 limestone	655
37a.	S12, NE, NE, NW	860	685 shale	640 limestone	625
56a.	S15, SW, SW, SE	855 limestone	714 shale	673 limestone	—230
			Glenwood shale	325	
			St. Peter sandstone	270	
			Trempeleau dolomite	—62	
			Franconian dolomite	—148	
			Galesville sandstone	—230	
61.	S23, SW, NW, NW	880	710 shale	670 limestone	—441
			St. Peter sandstone	260	
			Prairie du Chien dolomite	20	
67.	S23, NW, SE, NW	890	685 shale	660 limestone	—400
			St. Peter sandstone	340	
			Prairie du Chien dolomite	320	
68.	S23, NE, SE, SW	890	755 limestone	320 St. Peter sandstone	—438

TABLE 1.—Continued.

Township	Well Location	Surface Elevation	Bedrock Surface Elevation	Top of Rock Formation	Bottom of Well
			Prairie du Chien dolomite	—55	
78.	S26, NE, NE, NE	890	710 shale	680 limestone	—485
			Glenwood shale	334	
			St. Peter sandstone	239	
			Ironton Galesville sandstone	—256	
79a.	S26, NW, SE, NW	888	718 shale	698 Galena limestone	—432
			Platteville limestone	458	
			Glenwood shale	333	
			St. Peter sandstone	263	
			Prairie du Chien limestone	58	
			Trempeleau dolomite	—37	
			Franconian dolomite	—168	
			Ironton sandstone	—272	
			Galesville sandstone	—352	
			Eau claire sandstone	—432	
93.	S31, SW, SW, SE	870	486 limestone shelf	460 Platteville limestone	358
			St. Peter sandstone	378	
Cortland	T.40N., R.5E., (1-73) 34 drift wells, 39 bedrock wells.				
5.	S4, SW, SW, SE	880	725 shale	690 limestone	590
22.	S17, SE, SW, WC	880	607 shale	660 limestone	215
			St. Peter sandstone	215	
28.	S19, NW, NW, NE	900	716 shale	660 limestone	525
35.	S20, SE, SW, NW	880	715 shale	540 limestone	540
37.	S20, NE, SW, SE	890	765 shale	740 limestone	725
40.	S20, NW, NE, NE	895	740 shale	690 limestone	635
41.	S20, NE, NW, NW	895	745 shale	207 limestone	207
51.	S26, NE, SW, NE	860	700 shale	690 limestone	690
53.	S29, NW, NE, SE	900	765 shale	755 limestone	745
65.	S34, NW, NE, SW	870	790 shale	720 limestone	720
Virgil	T.40N., R.6E., (1-54) 33 drift wells, 21 bedrock wells.				
36.	S29, SE, SW, NW	870	710	630 limestone	610

TABLE 1.—Concluded.

Township	Well Location	Surface Elevation	Bedrock Surface Elevation	Top of Rock Formation	Bottom of Well
Lynnville	T.41N., R.2E., (1-5) 4 drift wells, 1 bedrock well.				
South Grove	T.41N., R.3E., (1-18) 11 drift wells, 7 bedrock wells.				
5.	S29, NE, NW, NW	870	770 shale	730 limestone	730
13.	S33, SW, SE, NW	930	760 shale	750 limestone	600
15.	S33, SE, SE, SW	940	770 shale	750 limestone	660
Mayfield	T.41N., R.4E., (1-22) 20 drift wells, 2 bedrock wells.				
6.	S28, NW, NE, NE	890	760 shale	745 limestone	505
13.	S32, SE, NE, NE	890	690 shale	600 limestone	500
14.	S33, SW, NE, NE	900	700 limestone	620 limestone	620
21.	S34, SW, NW, NW	870	720 limestone	490 limestone	490
Sycamore	T.41N., R.5E., (1-22) 15 drift wells, 7 bedrock wells.				
9.	S32, NE, NE, SC	850	705 limestone	315 St. Peter sandstone	1002
19.	S35, SW, NW, SE	910	740 shale	660 Galena limestone	—2195
				Glenwood shale 330	
				St. Peter sandstone 265	
				Trempeleau dolomite —105	
				Franconian dolomite —155	
				Ironton Galesville sandstone —240	
				Eau Claire sandstone —380	
				Granite —2195	
Burlington	T.41N., R.6E., (1-14) 11 drift wells, 3 bedrock wells.				
14.	S35, NE, SE, SE	925	715 shale	707 limestone	545

Total Number of Well Log Records
Drift Deepened to Bedrock Logs 50
Drift Wells 542
Rock Wells 338
Total.....930

reached, the Ordovician dolomites, the St. Peter sandstones or the Cambrian sandstone aquifers. Most of the deep city, factory, and railroad wells take water from these aquifers horizons. This group of wells number about 60 in the total group of wells studied. 100 of the remaining 338 bedrock wells are located on farms. Most cases these farm wells were drilled through the Niagaran and Maquoketa formations and into the Galena dolomite 10′ to 50′ before being completed. The jointed and fractured Galena formation furnishes easy means for the circulation of good quality artesian water.

In general, the water supply is excellent from both bedrock and glacial drift aquifers throughout the entire study area. In agreement with earlier reports by Suter and others (1959), and Templeton (1950), wells less than 80′ deep have proven to be unsatisfactory, except those shallow wells which are fed by spring water. The temperature of the water from wells which are drilled to 80′ depth, varies from 48 to 52 degrees Fahrenheit, while those deeper wells have water slightly warmer.

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Summary

A bedrock surface map and an areal geology map are formulated from 930 drilled well logs. Two structure cross sections are made from the data given by the deeper well records, one section extends across the study area in an east to west direction and the other from north to south across the central portion of the area. Interpretations are made for the data of the two sections and from the two maps. Glacial drift covers all the study area with thicknesses from 40′ to 350′. The glacial drift aquifer which is the most productive, occurs at the base of the drift layer. The buried bedrock surface has an average dip-slope to the south, including one large and two small parallel stream channels with 5′ per mile channel gradients southward. The areal geology consists of Galena-Platteville surfaces in the DeKalb quadrangle and Maquoketa shale slopes with Niagaran dolomite uplands in the Sycamore quadrangle. The rock strata have an average structural dip to the south-east of about 9′ per mile. Bedrock aquifers occur in the Ordovician (Galena-Platteville) dolomite, Ordovician (St. Peter) sandstone, Cambrian (Ironton-Galesville) sandstone, Cambrian (Eau Claire) sandstone, and Cambrian (Mt. Simon) sandstone. The Iron-Galesville aquifer is the best water-

resource for water wells in the study area. The study is intended to furnish local detailed geologic data which could prove useful in further studies of ground water reserves in this area.

References Cited

Bretz, J. Harlen. 1923. Geology and mineral resources of the Kings Quadrangle. Illinois Geol. Survey Bull. No. 43, pp. 205-304.

Caldwell, Loren T. 1936. A Study of the Stratigraphy and the PreGlacial Topography of the DeKalb and Sycamore Quadrangles. Unpublished Masters Thesis, University of Chicago, pp. 1-22.

Ekblaw, George E. 1938. Kankakee Arch in Illinois. Geol. Soc. America Bull., 49: 1425-1430. (Reprinted as Illinois Geol. Survey Circ. 40, 1938).

Foster, John W. 1956. Groundwater geology of Lee and Whiteside Counties, Illinois. Illinois Geol. Survey Rept. Inv. 194, p. 9.

Frye, J. C., and H. B. Willman. 1960. Classification of the Wisconsinan Stage in the Lake Michigan Glacial Lobe. Illinois Geol. Survey, Circ. 285, pp. 1-16.

Hackett, J. E. 1960. Ground-Water Geology of Winnebago County, Illinois. Illinois Geol. Survey, Rept. Inv. 213, pp. 40-49.

Horbert, Leland. 1946. Preglacial erosion surfaces in Illinois. Jour. Geology, 54(3) 179-192. (Reprinted as Illinois Geol. Survey Rept. Inv. 118, 1946, pp. 183-186.)

Horberg, Leland. 1950. Bedrock topography of Illinois. Illinois Geol. Survey Bull. 73, pp. 65-67.

Knappen, R. S. 1926. Geology and Mineral Resources of the Dixon Quadrangle, Illinois Geol. Surv. Bull. 49, p. 93.

Leighton, M. M. 1958. Important elements in the classification of the Wisconsin glacial stage. Jour. Geology, 66 (3) p. 288-309.

Suter, Max, Robert E. Bergstrom, H. F. Smith, Grover H. Emrich, W. C. Walton and T. E. Larson. 1959. Preliminary report on groundwater resources of the Chicago region, Illinois. Illinois Water Survey and Illinois Geol. Survey Coop. Ground-water Rept. 1, pp. 48-65.

Templeton, J. S. 1950. The Mt. Simon sandstone in northern Illinois. Trans. Il. Acad. Sci., 43: 151-159. (Reprinted as Illinois Geol. Survey Circ. 170, 1951.)

ANOMALOUS ALAR PLATE REGULATION IN THE EARLY CHICK NEURAL TUBE

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In previous studies attention has been given to numerous problems concerning regulatory mechanics and proliferation control mechanisms in the chick neural tube. In a number of instances studies were made of the regulative development, including proliferation patterns, occurring in response to induced neural tube defects (Birge and Hillemann, 1953; Birge, 1959a; 1959b; 1960; 1962). However, most attention has been given to the mesencephalic alar plate system of the early chick brain.

Subsequent to the removal of one mesencephalic alar plate, cells soon migrate into the deficient area from the opposite intact alar plate. Twelve to twenty-four hours after the operation, mitotic rate has increased throughout the intact alar plate tissue to 30-35% above normal. Proliferation continues at an accelerated rate, giving rise by day 7 to an optic tectum with a cell population approaching that of two normal mesencephalic alar plates of comparable development. By day 8 an *over-shoot* occurs in the growth of the regulating system, and this condition is sustained through day 9. During this period of *over-growth* the cell population averages 10% greater than that of two normal alar plates. Coincident with this *over-shoot*, mitotic activity drops below normal. Accordingly, the cell population decreases on day 10, showing a slight *under-shoot* before leveling off at the normal value (for two plates) by day 12.

The mechanism controlling proliferation, presumably a feedback system, appears quite sensitive to the size and/or density of the cell population, compensating for increases or decreases therein, by concomitant shifts in mitotic rate. Apparently the alar plate system is normally *self-limiting* or *self-regulating* in the control of proliferation. The regulative responses to hemilateral alar plate ablation are summarized in Table 1.

Though it has been well established that the regulatory pattern noted above is the usual response to early hemilateral alar plate ablation, a few exceptions to this pattern have been noted. They will be treated in this paper, as they bear on the subject of proliferation control.

Methods and Materials

This study concerns three chick embryos out of 138 which underwent hemilateral alar plate ablations during 28-38 hours of development. After each operation the embryo was reincubated and they were subsequently sacrificed at 2 to 20 days of development.

The three specimens in question were sacrificed at 4-5 days of development. In each instance the brain lesion was less complete than usual, leaving a significant amount of damaged tissue intact. All operations

TABLE 2.—Extent of alar plate regulation occurring subsequent to hemilateral ablation.

Age of Embryos	No. of Embryos Sacrificed	Overall Range of Regulative Growth	Average Extent of Regulative Growth	% size of Intact Alar Plate Area Compared With 2 Normal Plate Regions
Days		%	%	%
2	8 (8)	0-3	..	..
3	7 (4)	-16	10	55
4	5 (4)	18-38	28	64
5	5 (4)	35-52	44	72
6	7 (4)	47-68	54	77
7	4 (4)	60-72	70	85
8	8 (4)	102-120	116	108
9	6 (4)	108-123	120	110
10	10 (4)	75-93	86	93
11	7 (0)	.....	...	....
12	8 (4)	76-123	98	99
13	4 (0)	.....	....	....
14	8 (4)	96-109	102	101
15	8 (0)	.....	....	....
16	8 (4)	97-104	100	100
18	6 (4)	97-112	106	103
20	5 (2)	91-101	96	98

The extent of regulative growth is given as the percentage volume of tissue produced in excess of that normally formed by one alar plate. The number of embryos used in each age group for volumetric studies is given in parenthesis. (From Birge, 1959a.)

were performed as previously described (Birge, 1959a). Also, all other experimental procedures were maintained as previously noted.

RESULTS

Histological examinations of the three embyros in question revealed excessive infoldings of the dorsal half of the mesencephalon, including the alar plate system. In each case, the extensive infolding nearly filled or occluded the mesocoele, rendering the mesencephalon essentially solid in appearance. Also in each instance, the cellular population of the alar plates greatly exceeded that normally found to occur during the post-operative period.

Estimates of the population size, based on methods previously used (Birge, 1959a), indicated a five to eight-fold overproduction of cells, as compared to normal embryos of corresponding development. As noted above, cell production normally bears a distinct relationship to population size and/or density. When modest over-production results, cell division rate normally declines, presumably in response to such proliferation control mechanisms as are discussed above.

However, in the three instances noted herein, proliferation rate apparently was not subjected to such limitations or restrictions. It would seem that the mechanisms which normally limit proliferation in such systems were inoperative in these three cases, at least in part. This suggests that in a low percentage of cases, proliferation control mechanisms normally operative in the mesencephalic alar plate system of the chick may, under certain circumstances, break down, at least to some extent. As a consequence excessive over-proliferation may result. The three cases in point bear at least a superficial resemblance to carcinogenetic systems in this respect.

Literature Cited

Birge, W. J., and H. H. Hillemann. 1953. Metencephalic development and differentiation following experimental lesions in the early chick embryo. J. Exp. Zool., 124:545-570.

Birge, W. J. 1959a. An analysis of differentiation and regulation in the mesencephalon of the chick embryo. American Journal of Anatomy, 104: 431-463.

Birge, W. J. 1959b. Spontaneous alar plate hyperplasia in the chick embryo. Anatomical Record, 135:135-140.

Birge, W. J. 1960. Regulatory potentiality in the forebrain of the chick embryo. Anatomical Record, 137:475-484.

Birge, W. J. 1962a. Wound healing in the chick neural tube. Trans. Ill. Acad. Sci., 54:130-134.

Birge, W. J. 1962b. Proliferation patterns and control mechanisms in the mesencephalic alar plate system of the chick embryo. American Zoologist, 2:63.

Manuscript received December 11, 1961.

ACADEMY BUSINESS

SECRETARY'S REPORT FOR THE YEAR APRIL 29, 1961 - APRIL 27, 1962

G. ROBERT YOHE, *Secretary*

Council Meetings

The Council held four meetings during the year, as stipulated in the Constitution.

First Council Meeting. This was held in the Conference room of the Library of Eastern Illinois University, Charleston, Illinois, on Saturday morning, April 29, 1961, with the President, Dr. Walter B. Welch, presiding. Eleven persons, including eight members of the Council and a designated representative of another, were present.

The Secretary reported that 263 persons had registered for the 54th Annual Meeting; 177 of these were Academy members. The report on the Section meetings showed that all twelve had met on April 28, 1961; that 106 papers were presented, two were read "by title," and that the total of maximum attendance figures reported by the Section Chairmen was 409.

Dr. W. W. Grimm was appointed Chairman of the Sustaining Membership Committee.

The Educational Films Evaluation Committee was appointed; see TRANSACTIONS 54, 207 (1961).

The general idea of holding seminars for high school teachers on "Recent Advances in Biological Science," for which a National Science Foundation grant of $14,090 has been approved, at the four sites proposed by the Planning Committee (see under November 18 Council Meeting) was approved, and Dr. Norman D. Levine, Director of the project, was empowered to appoint an *ad hoc* committee to organize and operate these seminars. The Council approved the organization of a second series of similar seminars, these to be in the area of the Earth Sciences, and named Dr. J. C. Frye to designate someone to prepare a proposal.

Dr. Wesley J. Birge was reappointed Editor of the TRANSACTIONS, and the President and Dr. Birge were empowered to appoint the Board of Editors.

Mr. Arthur R. Wildhagen was reappointed as the Academy's Publicity Advisor.

The Planning Committee was reappointed except that Dr. W. J. Birge replaced Dr. P. C. Silva, and a new Committee called the Junior Academy Reevaluation Committee was appointed; see TRANSACTIONS 54, 207 (1961).

The Council approved requests submitted by two of the Sections that their Section names be changed. These were: "Science Education, Psychology, and Social Science Section" becomes the "Science Teaching Section," and the "Meteorology Section" becomes the "Meteorology and Climatology Section."

Approval was given to Dr. Klimstra's suggestion that $3,500 of the reserve fund derived from Patron and Sustaining member dues and designated for use in the Junior Academy work should be invested in short-term interest-bearing securities.

Dr. Klimstra was instructed to investigate the matter of the bonding of the Treasurer, and to report his findings to the Council.

Second Council Meeting. This was held in Room 433 of the Hotel St. Nicholas in Springfield on Saturday, November 18, 1961. Ten members of the Council were present, as well as fourteen Committee and Section Chairmen and some 25 others, mostly Junior Academy officers who were present only for the first part of the meeting.

The first hour of the meeting was devoted to a discussion of Junior Academy reports and problems, after which the Junior Academy officers withdrew to a separate meeting room.

President Welch announced and the Council approved the names of those who were appointed to the Editorial Board; see inside front cover of the TRANSACTIONS Vol. 54, Nos. 3 and 4.

The Secretary reported the following items which had been transacted by the

Council by mail ballot since the last meeting:

1. Approval of research grants to: Evan K. Oyakawa, Illinois State Normal University ($250.00); Sister Mary Marina, B.V.M., Mundelein College ($200.00); Howard G. Applegate, Southern Illinois University ($100.00); Boris Musulin, Southern Illinois University ($200.00); and William C. Ashby, Southern Illinois University ($49.00).

2. Approval of mailing out a letter asking members to support House Bill 1689.

3. Approval for the Illinois Society of Medical Research to use the Academy's mailing list to send information about Senate Bill 719.

4. Approval of a joint meeting co-sponsored by the Illinois Archaeological Survey and the Anthropology Section of the Academy to be held during the fall or winter of 1961-62.

In the absence of Dr. Klimstra, the treasurer's report was read by Dr. S. E. Harris and received by the Council. There were progress reports from several of the Section Chairmen.

Dr. S. E. Harris, Chairman of the Budget Committee, presented the budget for 1962. During discussion, several revisions were made; Dr. Harris then moved and Mr. Bamber seconded the adoption of the budget of $11,240, exclusive of National Science Foundation funds allocated to specific uses. This was approved.

Dr. Levine announced the following dates and sites for the high school teachers' seminars on "Recent Advances in Biological Science:"

February 9-10, 1962—
Lorado Taft Field Campus,
Northern Illinois University

February 23-24, 1962—
Allerton House,
University of Illinois

March 16-17, 1962—
Augustana College

April 13-14, 1962—
Little Grassy Lake Campus,
Southern Illinois University

Acting on a recommendation received from Dr. Lloyd Bertholf, President of Illinois Wesleyan University, the Council appointed Mr. Matthew Prastein, Associate Professor of Physics at Illinois Wesleyan as Second Vice-president in charge of local arrangements for the 56th Annual Meeting at Bloomington, April 25-27, 1963.

The Council approved a recommendation that the Junior Academy should amend its constitution so as to make possible the charging of entry fees on projects entered in the District and State Expositions.

Dr. Kenneth E. Damann's resignation as Chairman of the Teacher Training Committee was accepted, and Dr. Glen Q. Lefler of Eastern Illinois University was appointed as Dr. Damann's successor.

The Council expressed a favorable attitude toward the Junior Engineering Technical Society (JETS), but referred the matter of recommending possible cooperative action to the Junior Academy Re-evaluation Committee.

The question of bonding the Treasurer was tabled until the next meeting when the Treasurer himself could be present and explain the details.

The following changes in the current budget were approved:

1. The expenditure of $2,344.00 of the Academy's regular funds for Junior Academy activities.
2. An increase of $37.25 in the Council Activities item.
3. An increase of $153.69 in the Miscellaneous category.

The question of adding an item to future budgets to care for expenses of the President's office and of other officers of the Council was referred to the Planning Committee.

The Council recommended that the Junior Academy enforce all safety regulations strictly at all District and State Expositions.

Mr. Carlock spoke of attempts that were being made to encroach upon the lands of the Illinois Beach State Park, near Waukegan, and the Council instructed the Chairman of the Conservation Committee to write to the Governor and to the Director of the Department of Conservation, voicing the opinions of his Committee on this matter.

Third Council Meeting. This meeting was called to order at 9:40 A.M., February 17, 1962, in the Illini Union Building in Urbana, Illinois, by President Walter B. Welch. There were present ten Council members, five Committee Chairmen, ten Section Chairmen, and twenty-five other officers, guests, and officers of the Junior Academy.

Mr. Hopkins reported that there were currently 552 Science Clubs affiliated with the Junior Academy.

After further discussion of the Junior Academy matters, the Council and Academy officers adjourned to reconvene separately in Room 155, Altgeld Hall.

The Secretary gave a report showing the downward trend of Academy membership, and pointed out the need for attracting new members.

The Treasurer's report was presented and accepted.

The reports made by Second Vice-president Green and the Section Chairmen indicated satisfactory progress in the making of arrangements for the 55th Annual Meeting at Wheaton College.

The Audit Committee (S. E. Harris, Chairman, W. M. Lewis, and R. W. Kelting) presented their report, dated February 16, 1962. This was accepted.

Reports submitted by Dr. C. L. Kanatzar, Delegate to the A.A.A.S. and Miss Elnore Stoldt, Academy Conference Delegate, were received.

President Welch announced the appointment of three committees: (1) Nominations: F. J. Kruidenier, Chairman, H. B. Mills, Robert J. Smith, and Elnore Stoldt; (2) Resolutions: C. L. Kanatzar, Chairman, G. H. Boewe, Harold M. Kaplan, and Walter M. Scruggs; (3) Audit: William Lewis, Chairman, Ralph Kelting, and Miss Ellen Abbott. The Council approved these appointments.

Dr. Klimstra reported on several available plans for the bonding of the Treasurer, and said that he would prefer to have the office bonded. The Council approved this bonding, and empowered Dr. Klimstra to make the necessary arrangements.

The Council authorized the Treasurer to reimburse Miss Elnore Stoldt, Academy Conference delegate, for her transportation and hotel expenses for the Academy Conference meeting in Denver in December 1961.

The Secretary was instructed to prepare and submit to the membership for action at the 55th Annual Meeting amendments to the Constitution as given below:

The first of these amendments was prompted by discussion of an obviously unscientific and unsuitable paper which was submitted to one of the Sections, concerning which the Council approved a motion that "the Council place on record a statement to the effect that such papers . . . are not suitable for presentation at any of the Academy's Section Meetings."

1. Article III, Section 2, to be amended so as to provide for the rejection of papers submitted for oral presentation if the Section Chairman deems them unsuitable, provided that the member submitting such rejected paper shall have the right to appeal the decision to the Council.

2. Article V, Section 1, to be amended so as to provide for eliminating the office of Collegiate Section Coordinator and further to increase the number of elected Councilors from 3 to 4, to be elected in rotation, each for a 4-year term, and that the terms of the present elected Councilors be extended as necessary to fit into this rotation.

3. Article X, Section 6, to be amended so as to provide that the President, as well as the Secretary and Treasurer, may be reimbursed for expenses while attending Council meetings and Annual meetings.

The Council granted approval for the Anthropology Section to hold another cooperative meeting with the Illinois Archaeological Survey as was done in December 1961.

Chairman Hopkins of the Junior Academy entered to report that the Junior Academy had approved the plan suggested by David Reyes-Guerra, State Director of the Junior Engineering Technical Society that the J.E.T.S. State meet and the University of Illinois Engineering Open House be held on the same week-end as the Junior Academy State Exposition in 1963. The Council approved this plan on a trial basis.

Questions concerning the suitability of the name "Transactions" for the Academy's journal, the possible establishment of emeritus membership in the Academy, and the matter of creating the rank of "Fellow" of the Academy as suggested in Dr. Kanatzar's report as A.A.A.S. delegate, were referred to the Planning Committee.

Fourth Council Meeting. Following a dinner in the "Twenty-seven Room" of the College Dining Hall at Wheaton College, Wheaton, Illinois, on April 26, 1962, President Welch called the meeting to order at 7:00 P.M. Eleven Council members, nine Section Chairmen, and ten other officers and Committee Chairmen were present.

The Secretary's report included the following membership statistics as of April 23, 1962:

Life Members	36
Student Members	4
Regular Annual Members	1242
Sustaining Members	22
Patron Members	25
Total	1329

Excluding Sustaining and Patron Members, the membership by Sections is:

Anthropology	40
Aquatic Biology	30
Botany	151
Chemistry	276
Conservation	9
Geography	69
Geology	108
Meteorology and Climatology	20
Microbiology	13
Physics	100
Science Teaching	109
Zoology	256
No Section Designated	
Individuals	64
Clubs	18
Libraries	19
Total	1282

The Secretary's report also called attention to the fact that of the 160 authors and co-authors listed on the Section programs for the 55th Annual Meeting, 57.5% were not members of the Academy.

Mr. Hopkins, Chairman of the Junior Academy, reported that there were 617 Science Clubs registered with the Junior Academy; that over 500 papers had been submitted in the competition for the papers sessions at the State Exposition; and that the National Science Foundation had rejected our application for a grant for the coming year.

Mr. Milton Thompson, reporting for Dr. Deuel, Librarian, stated that Volume 54, Nos. 3 and 4 had been mailed to the members on April 19, and that about $5900 remains in the printing fund.

Dr. Wesley J. Birge, Editor of the TRANSACTIONS, submitted a report which was summarized by the Secretary. It showed that 13 papers had been published since November 17, 1961 (in Volume 54, Nos. 3 and 4); that 13 manuscripts are currently in press (Volume 55, No. 1); and that during this period, 8 additional manuscripts had been accepted, 4 rejected, 6 are being revised, and 7 are being reviewed. Beginning with Volume 55, four separate issues per volume will be printed.

Reports of the Section Chairmen and the Committee Chairmen were largely routine preliminaries to the functioning of and reporting to the meetings of April 27.

Dr. Elaine Bluhm reported that in view of the fact that the National Science Foundation had not approved the Academy's most recent request for a grant, the Junior Academy Re-evaluation Committee had met and approved the following recommendation: " . . . that the Junior Academy of Science set up a system for collecting a state registration fee, prorated on the basis of school size, which would guarantee an income of $11,000 to $12,000 per year to cover the cost of the State Chairman's office and the expenses of the State Exposition at the University of Illinois, Urbana." After some discussion, this was amended to provide that each school so registered should receive the TRANSACTIONS for the year involved; the recommendation was then approved by the Council.

Dr. Levine's report on the four seminars for high school biology teachers was summarized by the Secretary; it indicated that these seminars were deemed "highly successful," and that such seminars could well be continued in future years.

A question of the matter of Academy policy in regard to permitting equipment manufacturers to exhibit their products at Annual Meetings was referred to the Planning Committee.

Professor Matthew Prastein, Second Vice-president for the 1963 meeting, reported that the construction of the new Science building at Illinois Wesleyan was behind schedule; that it obviously would not be available for the 1963 meeting, and that it would, therefore, be necessary for Illinois Wesleyan to cancel the invitation for the Academy to hold its 56th Annual Meeting there.

The 55th Annual Meetings

General Meeting. The general session of Friday morning, April 27, 1962, held in the Main Auditorium of Pierce Chapel, Wheaton College, Wheaton, Illinois, was called to order by President Walter B. Welch at 10:00 A.M.

Dr. V. R. Edman, President of Wheaton College, gave the address of welcome. This was followed by Dr. Welch's Presidential address, "This I Would Like to Know," and the address, "An American Educator in Afghanistan," by Dr.

Elbert H. Hadley, Professor of Chemistry at Southern Illinois University.

Section Meetings. On Friday afternoon, April 27, all Sections held meeting as set forth in the printed program. One hundred sixteen papers were presented, six were read "by title," and the sum of the maximum attendance figures reported by the Section Chairmen was 404. The new Chairmen named by the Sections are listed elsewhere in the TRANSACTIONS, under "Officers for 1962-63."

THE ANNUAL BUSINESS MEETING

The Business Meeting was called to order at 5:00 P.M., April 27, 1962, in the Main Auditorium of Pierce Chapel, Wheaton College, Wheaton, Illinois, by President Walter B. Welch. About 55 members were present.

President Welch called attention to the fact that the minutes of the 54th Annual Business Meeting had been published in the TRANSACTIONS, Volume 54, pp. 196-208. The Secretary said, "Mr. President, I move the acceptance of the report of the 54th Annual Meeting as published, and also of the summary of the year's activities as given in the President's Annual letter." Dr. Evers seconded and the motion carried.

Reports of Officers

President Welch reported that Illinois Wesleyan University had found it necessary to withdraw the invitation for the Academy to meet there in 1963, and that the Academy would welcome invitations for both 1963 and 1964.

Secretary Yohe reported items which are recorded in the foregoing reports of Council meetings.

Treasurer Klimstra's report is published herewith. This report was accepted by passage of a motion made by Dr. Klimstra and seconded by Dr. Evers.

Librarian Deuel's report, presented by Milton Thompson, was that recorded under the April 26 Council meeting.

Reports of Standing Committees

Dr. Kaplan (Animal Experimentation in Research), Dr. Klimstra (Conservation), and Dr. Lefler (Teacher Training) referred to resolutions to be presented later in the meeting.

President Welch summarized the budget for 1962, which had been approved by the Council at the November 18, 1961, meeting.

The following report submitted by Dr. Van Lente, Chairman of the Research Grants Committee, was read by the Secretary:

The Research Grants Committee recommends that the following grants be awarded:

Wm. C. Ashby, Southern Illinois University .....$	75.00
Sister M. Paulita Springer, Rosary College	160.00
Benedict J. Jaskoski, Loyola University	50.00
J. Alan Holman, Illinois State Normal University.	279.00
George Seketa, Southern Illinois University	150.00
Aristotel J. Pappelis, Southern Illinois University...	150.00
Total .....$	864.00
Available from the A.A.A.S.....$	864.00

A motion for the approval of these grants was made by Dr. Yohe, seconded by Mr. Bamber, and passed.

The report of the Science Talent Search Committee was summarized by the Secretary. It contained the names of 2 National winners, 25 National and 11 State Honorable mentions in the Westinghouse Science Talent Search, and named Gerald Ralph Smith of Greenville High School, Greenville, as winner of the Frank H. Reed Memorial Award.

Dr. Grimm, reporting for the Sustaining Membership Committee, stated that the income from sustaining and patron memberships since November, 1961, was approximately $4,000.00, which is about $1,000.00 less than for the corresponding period a year ago.

Reports of Special Committees

The report of the Audit Committee was received by the Council at the February 17 meeting; the report of the Educational Films Evaluation Committee will be submitted later to the TRANSACTIONS for publication.

The report of the Junior Academy Reevaluation Committee, which had been amended and then approved by the Council on April 26 (see above), was approved in this final form by the Academy.

The following Constitutional amendments, which had been sent to all members on March 20, 1962, were read and

explained by the Secretary, and voted upon separately. Deletions are in parentheses; additions are italicized.

Article III, Section 2.

> Regular individual members in good standing shall have the privilege of voting at the annual meeting, holding office, offering papers for presentation at meetings *subject to the approval of the appropriate Section Chairman and with right of appeal to the Council*, having (such) papers published *in the Transactions* if accepted by the Board of Editors, and receiving one copy of the current Transactions of the Academy. No member in arrears shall receive the Transactions for any year for which he is or remains in arrears.

Dr. Frye moved and Dr. Klimstra seconded that this amendment be adopted. Carried.

Article V, Section 1.

> The Council shall consist of the President, First Vice-president, Second Vice-president, Secretary, Treasurer, Librarian, General Chairman of the Junior Academy, (Coordinator of the Collegiate Section), the immediate past President, the immediate past Secretary, the immediate past Treasurer, each for a term of one year, and (three) *four* Councilors-at-large. These last shall be elected for (three-) *four-* year terms, only one being elected each year, except that the first year this provision is put into effect (one Councilor-at-large shall be elected for a one-year term, one for a two-year term, and one for a three-year term.) *the terms of the three incumbent Councilors-at-large shall each be extended one year and a fourth Councilor-at-large shall be elected for a four-year term.*

Dr. Yohe moved and Mr. Bamber seconded that this amendment be adopted. Carried.

Article X, Section 6

> The *President, the* Secretary and the Treasurer shall be reimbursed for their expenses while attending Council meetings and annual meetings . . .

Dr. Evers moved and Dr. Grimm seconded the approval of this amendment. After discussion and explanations by Dr. Bennett, Ekblaw, Grimm, Klistra, and Green, the motion carried.

The Resolutions Committee (C. L. Kanatzar, Chairman, G. H. Boewe, H. M. Kaplan, and W. M. Scruggs) submitted the following resolutions read by Dr. Kanatzar; all were approved by the Academy:

1. APPRECIATION TO HOST

Whereas the Administration, Faculty, and Staff of Wheaton College have provided the arrangements for this Fifty-fifth Annual Meeting of the Illinois State Academy of Science,

Be it resolved that the Academy express its thanks to all who have served in any capacity in promoting the interests and activities of the members during this meeting, and especially to

Dr. V. Raymond Edman, President of the College,

Dr. Frank O. Green, Second Vice-President of the Academy, in charge of local arrangements,

the Committee on Local Arrangements, including Doctors Leedy, Brand, Kraakevik, Wright, Boardman, and Mack, and Mr. Haddock, and

the Divisions of Food Service, Buildings and Grounds, and Publicity.

Be it further resolved that the Secretary be directed to send copies of this resolution to those specifically named.

2. APPRECIATION OF SERVICE

Whereas

the Departments of Biology, Chemistry, and Geology, of Wheaton College,

Mr. Swink, of the Morton Arboretum, and

the Illinois State Geological Survey have accepted the responsibility for sponsoring the Field Trips to the Argonne National Laboratory, the Morton Arboretum, and the surrounding geological areas, as a significant portion of the program for the Fifty-fifth Annual Meeting of the Academy.

Be it resolved that the Academy express its thanks to those responsible for organizing and conducting these Field Trips.

Be it further resolved that the Secretary be directed to send copies of this resolution to those specifically named.

3. APPRECIATION OF DISTINGUISHED SERVICE

Whereas Dr. G. R. Yohe, of the Illinois State Geological Survey, has served

the Academy in a diligent and productive manner as Secretary for the past three years,

Be it resolved that the members of the Academy express their appreciation for his service, and that the Secretary-elect be directed to send him a letter of commendation.

4. PROFESSIONAL EDUCATION REQUIREMENT FOR CERTIFICATION OF TEACHERS IN THE SECONDARY SCHOOLS

Whereas a communication from the Office of the Illinois State Teachers Certification Board, dated June 19, 1961, was received by the Teacher Training Institutions, County Superintendents of Schools, and Local School Administrators, in the state of Illinois, and

Whereas in this letter concerning secondary school certification in the state of Illinois appears the recommendation that the present requirement of sixteen (16) semester hours for professional education courses be increased to eighteen (18) semester hours by legislative action.

Be it resolved that the Illinois State Academy of Science oppose this recommendation.

Be it further resolved that the Academy authorize its Committee on Teacher Training to support by any appropriate means the retention of the present requirement of sixteen (16) semester hours of professional education courses for the secondary school certificate.

Be it further resolved that the Secretary be directed to send a copy of this resolution to the Illinois State Teachers Certification Board, Springfield, Illinois; to the State Superintendent of Public Instruction, Springfield, Illinois; and to the academic societies, associations, and organizations in the state of Illinois, requesting them to support this resolution, and to direct a letter of support to the Illinois State Teachers Certification Board and to the State Superintendent of Public Instruction, and to any other persons or groups concerned.

5. NATURE CONSERVANCY

Whereas, it is most apparent that natural areas are rapidly disappearing from our State, and that efforts to preserve many of these for posterity are frequently thwarted because of financial difficulties, ignorance, and irresponsibility, and

Whereas the Illinois Chapter of Nature Conservancy has been partially successful in stemming this trend towards the loss of natural areas, particularly along Rocky Branch, northwest of Marshall in Clark County,

Be it resolved that the Academy recognize the efforts of this agency by instructing the Secretary to write to Dr. Lewis J. Stannard, Chairman of the Illinois Chapter of Nature Conservancy, indicating the Academy's recognition of the outstanding contributions which Nature Conservancy is making in our State.

Be it further resolved that the members of the Academy support Nature Conservancy in its campaign for the preservation of additional natural areas.

6. PRAIRIE CHICKEN FOUNDATION

Whereas during the past few years the populations of prairie chickens in Illinois have shown a drastic decline in numbers, and

Whereas the recently formed Illinois Prairie Chicken Foundation has been making extensive efforts through the contributions of time, money, and talents of many persons, agencies, and organizations throughout the State to establish refuge areas to insure the preservation of this native bird, and

Whereas these efforts have resulted in the purchase of a 77-acre tract near Bogota in Jasper County,

Be it resolved that the Academy extend to the Prairie Chicken Foundation appreciation of the Foundation's efforts to save the prairie chicken, and that the members of the Academy support the Foundation's program.

Be it further resolved that the Secretary be instructed to send a copy of this resolution to the Chairman of the Board of Directors of the Prairie Chicken Foundation.

7. NATURE PRESERVES

Whereas, a bill prepared for the purpose of establishing the necessary procedure and organization for obtaining and administering nature preserves was approved unanimously to both houses of the 1961 General Assembly, and

Whereas this bill was subsequently vetoed by the Governor because of his objection to certain aspects of the form in which the bill was prepared, and

Whereas Governor Kerner indicated his sympathy with the objectives of the bill, and

Whereas it is in the best interests of the citizens of Illinois to present a revised nature preserves bill to the 1963 Illinois General Assembly,

Be it resolved that the Academy indicate its support of the preparation of a revised bill.

Be it further resolved that the Secretary write to Mr. George Fell, Chairman of the Citizens Committee for Nature Conservation, commending him in his many efforts relating to this bill as well as to other activities concerned with the conservation of natural resources in Illinois.

8. ILLINOIS BEACH STATE PARK

Whereas the Illinois Beach State Park represents not only one of an insufficient number of parks in Illinois but also an unusual and unique natural area, and

Whereas the Illinois Department of Conservation's Advisory Board has recommended to Governor Kerner that the demands and interests of the city of Waukegan to purchase or in some way obtain 160 acres not be entertained,

Be it resolved that the Academy commend the Governor and the Director, William T. Lodge, Illinois Department of Conservation, on the stand which they have taken to preserve this unique and important Illinois park.

Be it further resolved that the Secretary be directed to send a copy of this resolution to the Governor and the Director.

9. ANIMAL STUDIES IN ILLINOIS PUBLIC SCHOOLS

Whereas the basic aim of biological studies that involve animals is to achieve an understanding of life and to advance our knowledge of the processes of life, and

Whereas the ethical and educational benefits to be gained thereby lead to a respect for life, and

Whereas biological studies involving animals are an important means of illustrating biological principles and inspiring elementary and secondary school students to consider careers in the biological, medical, and veterinary sciences, and

Whereas there is great need for future scientists in all of the veterinary, medical, and biological sciences; that this area is important to the national defense, and

Whereas the Science Curriculum Studies of the American Institute of Biological Sciences contain numerous projects that involve the use of animals at the pre-college level; and

Whereas guiding standards for pre-college animal studies have been approved by a number of professional scientific societies, including the National Academy of Sciences-National Research Council, the American Institute of Biological Sciences, the National Society for Medical Research, and the Animal Care Panel, and

Whereas the Illinois School Code stating that animals shall not be used for study or demonstration in Illinois public schools handicaps proper teaching of biology,

Be it resolved that the Illinois State Academy of Science support the principle of the need of animal studies in the public schools of Illinois; that the portion of the school code forbidding the use of animals for such studies be repealed; and that a bill comparable to House Bill 1689, introduced into the 72nd Illinois General Assembly in 1961, permitting and regulating the use of animals in biological studies in the public schools of Illinois, should become law.

Be it further resolved that the Committee on Animal Experimentation in Research be authorized to cooperate with other groups to effect a change in the statute.

10. UNCLAIMED POUND ANIMALS FOR RESEARCH

Whereas the basic aim of scientific studies that involve animals is to achieve an understanding of life, and to advance our knowledge of the processes of life, and

Whereas the progress of medical science has contributed greatly to the health, happiness and longevity of mankind and promises to be equally rewarding in the future, and

Whereas further progress cannot be achieved without the use of living animals for experimentation, and

Whereas animal experimentation is conducted by humanely motivated investigators and with every care to avoid undue discomfort to the animals involved, and

Whereas the Illinois State Academy of Science endorses the use of living dogs and cats and other animals for research purposes by responsible investigators in approved laboratories,

Be it resolved that the Illinois State Academy of Science lend its support to legislation at the state level that would make available to approved research and teaching institutions animals that otherwise would be killed in public pounds.

Be it further resolved that the Committee on Animal Experimentation in Research be authorized to cooperate with other groups to effect such legislation.

11. NECROLOGY

Whereas the Academy has lost by death within the past year the following members:

C. C. Burford (September 9, 1961)
John E. Coe (Life Member) (April 11, 1961)
John W. Cralley (February 4, 1961)
L. O. Gill (July 11, 1961)
Harriet F. Holmes (Life Member)
Edith Putnam Parker (October 10, 1961)
A. J. Throop (1961)
Horatio C. Wood

and

Whereas death has come to two Past Presidents of the Academy,

Fay-Cooper Cole (September 3, 1961), serving in 1931-32, and George D. Fuller (Life Member) (November 22, 1961), serving in 1938-39,

Be it resolved that the members of the Academy express their sorrow by rising for a moment of silence.

Dr. Kanatzar moved that all members present should stand for a moment of silence. The unanimity of this action constituted approval of this resolution.

The report of the nominating committee (Dr. F. J. Kruidenier, Chairman, Dr. H. B. Mills, Dr. J. W. Neckers, and Dr. R. J. Smith) was read by the Secretary in the absence of Dr. Kruidenier; in Committee nominations, only the names of the Chairmen were read. Mr. Bamber moved and Mr. Austin seconded that the report be received. Carried. Dr. Welch called for any nominations that might be made from the floor. There being none, Dr. Ekblaw moved and Dr. Schoffman seconded that the nominations be closed and that the Secretary cast a unanimous ballot for this slate of officers. Carried. The names of the officers and committees thus elected, together with others elected by the Council or the Sections, or appointed by the President, are published elsewhere in the TRANSACTIONS.

Dr. Ekblaw moved that the members present stand in recognition of the faithful efforts made by the officers of the Academy during the past year. There were numerous seconds, and those present rose to their feet.

The meeting was adjourned at 6:15 P.M.

Secretary's note: Complete and detailed minutes and committee reports, of which the above is an abstract, are on file in the Secretary's office.

EVENING PROGRAM

The Academy Banquet was held in the College Dining Hall of Wheaton College at 6:15 P.M., Friday, April 27, 1962.

The Annual Public Lecture, "The Host as a Growth Medium for the Parasite," by Dr. E. D. Garber, Professor of Microbiology and Plant Pathology at the University of Chicago, was delivered in the Main Auditorium of Pierce Chapel at 8:00 P.M.

TREASURER'S ANNUAL REPORT

January 1 - December 31, 1961

BALANCE CARRIED FORWARD, January 1, 1961			$ 7,118.04
RECEIPTS:			
Dues			
Regular		$ 6,917.00	
Sustaining and Patron		4,692.00	
Registration (Charleston)		111.50	
AAAS Research Grants		1,449.00	
Interest, U. S. Bonds		88.25	
Interest, Savings and Loan Assn.		223.50	
Return of Loan to Hoffman		285.32	
Refunds from Districts		340.42	
			$ 14,106.99
EXPENDITURES:			
Council		$ 337.25	
Secretary's Office		850.50	
Treasurer's Office		791.22	
Editor's Office		200.06	
Librarian		319.25	
AAAS Research Grants		1,449.00	
Honoraria		350.00	
Membership Committee		17.65	
Sust. and Patron Membership Comm.		.....	
Planning Committee		.....	
Publications		.....	
Refunds		6.00	
State Savings and Loan Assn.		4,500.00	
Miscellaneous		303.69	
Junior Academy			
General	$ 2,300.44		
Science Talent Search	501.80		
		$ 2,802.24	
			$ 11,926.86
GRANTS:			
NSF G-12402			
Balance as of January 1, 1961		$ 3,470.19	
Refund from Districts		148.17	
			$ 3,618.36
Expenditures:			
Salary and Wages		$ 398.28	
Speaker Expense		136.00	
Travel		82.63	
Publications		40.20	
Photography		380.09	
Research Paper Program		200.00	
State Chairman Elect		54.81	
Judging Chairman		89.45	
Telephone and Postage		71.63	
Substitute Teacher		25.00	
District Expenses		2,140.27	
			$ 3,618.36
NSF G-17016			
Receipts:			
June 1, 1961			$ 7,650.00

Expenditures:		
Salary and Wages	$ 496.00	
Supplies	1,194.05	
Travel	267.10	
Publications	2,154.87	
Telephone and Postage	320.00	
Substitute Teacher	55.00	
Other Expense	100.00	
		$ 4,587.02
Balance as of December 31, 1961		$ 3,062.98

NSF G-17291

Receipts:		
May 15, 1961	$ 7,045.00	
December 27, 1961	7,045.00	
		$ 14,090.00
Expenditures:		
Salary and Wages	$ 17.50	
Supplies	156.10	
Travel	77.60	
Publications	60.90	
Other Expense	17.60	
		$ 329.70
Balance as of December 31, 1961		$ 13,760.30

PERMANENT FUND

Life Membership		
Cash	$ 250.00	
Bonds	1,700.00	
		$ 1,950.00
RESERVE FUNDS		
U. S. Bonds	$ 1,800.00	
State Savings and Loan Assn.	6,000.00	
		$ 7,800.00
FRANK REED MEMORIAL FUND		
Balance Carried	$ 641.98	
Council	50.00	
Interest	44.45	
Honorarium, Yohe	150.00	
		$ 886.43
Cash in Carbondale National Bank as of December 31, 1961		$ 22,096.37
Balance NSF 17016	$ 3,062.98	
Balance NSF 17291	13,760.30	
Outstanding Checks	398.38	
Permanent Fund Cash	250.00	
		$ 17,471.66
Total Uncommitted Cash as of December 31, 1961		$ 4,624.71

ILLINOIS STATE ACADEMY OF SCIENCE
OFFICERS, COMMITTEES, AND SECTION CHAIRMEN
FOR 1962-63

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LIBRARIAN: Thorne Deuel, Illinois State Museum, Springfield.

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G. H. Boewe (to 1964), State Natural History Survey, Urbana.

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Norman D. Levine (to 1966), 143 Vet. Medicine Building, University of Illinois, Urbana.

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*EDITOR: Wesley J. Birge, 318 Natural History Building, University of Illinois, Urbana.

*PUBLICITY ADVISOR: Arthur R. Wildhagen, 222a Illini Hall, University of Illinois, Urbana.

*DELEGATE TO THE AAAS: C. Leplie Kanatzar, MacMurray College, Jacksonville.

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Thorne Deuel, State Museum, Springfield.

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Robert Schoffman, Spalding Institute, Peoria.

F. R. Steggerda, University of Illinois, Urbana.

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John C. McGregor, University of Illinois, Urbana.

Carroll L. Riley, Southern Illinois University, Carbondale.

Sol Tax, 1126 East 59th Street, Chicago.

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Walter A. Brown, Illinois State Normal University, Normal.

James H. Grosklags, Northern Illinois University, DeKalb.

J. W. Neckers, Southern Illinois University, Carbondale.

---

* Appointed by the President or by the Council.

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Harlow B. Mills, State Natural History Survey, Urbana.

Ruben L. Parson, Northern Illinois University, DeKalb.

Henry Sather, Western Illinois University, Macomb.

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Esther Griffith, Illinois State Normal University, Normal.

John Harrison, State Geological Survey, Urbana.

Ernest L. Karlstrom, Augustana College, Rock Island.

Russell L. Mixter, Wheaton College, Wheaton.

I. Edgar Odom, State Geological Survey, Urbana.

Walter E. Parham, State Geological Survey, Urbana.

Herbert Priestley, Knox College, Galesburg.

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Eleanor Dilks, Illinois State Normal University, Normal.

Ralph J. Miller, Greenville College, Greenville.

Mark Paulson, Bradley University, Peoria.

Fr. William J. Shonka, St. Procopius College, Lisle.

Elnore Stoldt, 759 S. Church Street, Jacksonville.

H. F. Thut, Eastern Illinois University, Charleston.

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Hal. F. Fruth, 5032 W. Morse, Skokie (Physics).

Leland Harris, Knox College, Galesburg (Chemistry).

Charles K. Hunt, Hinsdale (Chemistry).

Donald P. Rogers, University of Illinois, Urbana (Botany).

John D. Roslansky, University of Illinois, Urbana (Zoology).

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Robert A. Evers, Illinois State Nat. History Survey, Urbana.

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Milton Thompson, Illinois State Museum, Springfield.

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A. Frances Johnson, Rockford College, Rockford.

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David R. Lauck, Chicago Academy of Sciences, 2001 N. Clark, Chicago.

R. Maurice Myers, Western Illinois University, Macomb.

Sister M. Jane Preising, College of St. Francis, Joliet.

Robert C. Waddell, Eastern Illinois University, Charleston.

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Ellen Abbott, Southern Illinois University, Carbondale.

Boris Musulin, Southern Illinois University, Carbondale.

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Joseph Caldwell, Illinois State Museum, Springfield.

Carleton Condit, Illinois State Museum, Springfield.

Melvin O. Foreman, Eastern Illinois University, Charleston.

Matthew Prastein, Illinois Wesleyan University, Bloomington.

James M. Sanders, Chicago Teachers College, Chicago.

Walter M. Scruggs, Eastern Illinois University, Charleston.

Frank Wittwer, Office of Public Instruction, Springfield.

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Elaine A. Bluhm, 137 Davenport Hall, University of Illinois, Urbana.

Robert A. Evers, Illinois Natural History Survey, Urbana.

C. Leplie Kanatzar, MacMurray College, Jacksonville.

Elnore Stoldt, 759 S. Church Street, Jacksonville.

Norman D. Levine, 143 Vet. Medicine Bldg., U. of Illinois, Urbana.

George R. Abraham, Lincoln-Way Community High School, New Lenox.

William A. Hill, Naperville Community High School, Naperville.

Donald G. Hopkins, Carl Sandburg High School, Orland Park.

Sister Mary Ivo, BVM, Immaculata High School, Chicago 13.

Seichi Konzo, 126 M. E. Bldg., University of Illinois, Urbana.

Paul M. Wright, Wheaton College, Wheaton.

NOMINATIONS: G. R. Yohe, *Chairman*, State Geological Survey, Urbana.

William C. Ashby, Southern Illinois University, Carbondale.

Kenneth H. Harmet, Northern Illinois University, DeKalb.

F. J. Kruidenier, University of Illinois, Urbana.

R. Maurice Myers, Western Illinois University, Macomb.

PLANNING: (Chairman to be elected by the Committee).

Wesley J. Birge, 318 Natural History Bldg., U. of Illinois, Urbana.

Kenneth E. Damann, Eastern Illinois University, Charleston.

John A. Harrison, State Geological Survey, Urbana.

Joan Hunter, West Senior High School, Aurora.

F. J. Kruidenier, 322 Natural History Bldg., U. of Illinois, Urbana.

N. D. Levine, 143 Vet. Medicine Bldg., U. of Illinois, Urbana.

Ralph J. Miller, Greenville College, Greenville.

W. W. Wantland, Illinois Wesleyan University, Bloomington.

Carl Weatherbee, Millikin University, Decatur.

RESOLUTIONS: (For 1962; new committee to be appointed at fall Council meeting).

C. Leplie Kanatzar, *Chairman*, MacMurray College, Jacksonville.

G. H. Boewe, Illinois Natural History Survey, Urbana.

H. M. Kaplan, Southern Illinois University, Carbondale.

W. M. Scruggs, Eastern Illinois University, Charleston.

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(Elected by the Sections)

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AQUATIC BIOLOGY: Leo F. Rock, Illinois Department of Conservation, 705 11th Street, Sterling.

BOTANY: Dr. Frank A. Crane, University of Illinois, College of Pharmacy, 833 S. Wood Street, Chicago 12.

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CONSERVATION: Dr. Donald T. Ries, Illinois State Normal University, Normal.

GEOGRAPHY: Dr. Stanley Shuman, Illinois State Normal University, Normal.

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MICROBIOLOGY: Dr. Leslie R. Hedrick, Illinois Institute of Technology, 3300 S. Federal Street, Chicago.

PHYSICS: Dr. Howard H. Claassen, Wheaton College, Wheaton.

SCIENCE TEACHING: Otto Ohmart, Anna-Jonesboro High School, Anna.

ZOOLOGY: Dr. Jack Bennett, Northern Illinois University, DeKalb.

Note: The CHEMISTRY Section named as Chairman-elect, Dr. Bruce M. Campbell, MacMurray College, Jacksonville.

1962-63

PREPARATION OF MANUSCRIPTS FOR THE TRANSACTIONS

For publication in the *Transactions*. articles must present significant material that has not been published elsewhere. Review articles are excepted from this provision, as are brief quotations necessary to consider new material or varying concepts. All manuscripts must be typewritten, double spaced, with at least one-inch margins. The original copy, not the carbon copy, is to be submitted.

Titles should be brief and informative. The address or institutional connection of the author appears just below the author's name. Subtitles or center headings should be used; ordinarily one uses substitles such as *Introduction*, *Acknowledgments*, *Materials*, *Methods*, *Results*, *Discussion*, *Summary*, and *Literature Cited*. All papers should have a summary.

No footnotes are to be used.

The section entitled *Literature Cited* must include all references mentioned in text. It is not to include any other titles. No references to the literature are to be placed in footnotes. Citations under *Literature Cited* are as shown below:

Doe, John H. 1951. The life cycle of a land snail. Conchol., 26(3): 21-32, 2 tables, 3 figs.

Doe, John H. 1951. Mineralogy of Lower Tertiary deposits. New York, McGraw-Hill Book Co., iv + 396 pp.

Quoted passages, titles, and citations must be checked and rechecked for accuracy. Citations to particular pages in text are Doe (1908, p. 21) or (Doe, 1908, p. 21); general citation in text is Doe (1908) or (Doe, 1908).

Tabular information should be kept at a minimum. Tables should not be more than one page in length. Do not duplicate tabular data in text. Headings for tables and columns should be brief. Reduce to the barest essentials, or preferably omit, explanatory notes on tables. Each table and its heading should be on a single page; do not place any table on the same page with text.

Photographs should be hard, glossy prints of good contrast. Graphs, maps and other figures reproduce best when prepared for at least one-half reduction; lettering, numerals, etc. on all figures in a manuscript should be worked out to proper size for such reduction. Line widths, letter size etc. should be uniform from figure to figure within a published paper. Figures should be drawn on good quality white paper or on drawing board. Use only India ink. Use a lettering device (Leroy or Wrico) for numerals and words; do not print "free-hand."

Legends for photographs and figures should be brief; type them on a separate sheet of paper. Indicate figure number and your name on back of illustration; do not write with pencil on the backs of photographs.

Authors will receive galley proofs; these should be read carefully and checked against the original manuscript. Reprints may be ordered at time galley proofs are returned to the Editor.

WESLEY J. BIRGE,
University of Minnesota, Morris
Morris, Minn.


ILLINOIS
Land of Lincoln

Transactions

of the

Illinois State Academy of Science

Volume 55
Nos. 3 and 4
1962

Springfield, Illinois

TRANSACTIONS of the ILLINOIS STATE ACADEMY of SCIENCE

The current *Transactions* may be obtained by payment of annual dues.

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TRANSACTIONS

OF THE

ILLINOIS STATE ACADEMY OF SCIENCE

VOLUME 55 - 1962 Nos. 3 and 4

ILLINOIS STATE ACADEMY OF SCIENCE

AFFILIATED WITH THE

ILLINOIS STATE MUSEUM DIVISION

SPRINGFIELD, ILLINOIS

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

OTTO KERNER, *Governor*

JULY 10, 1963

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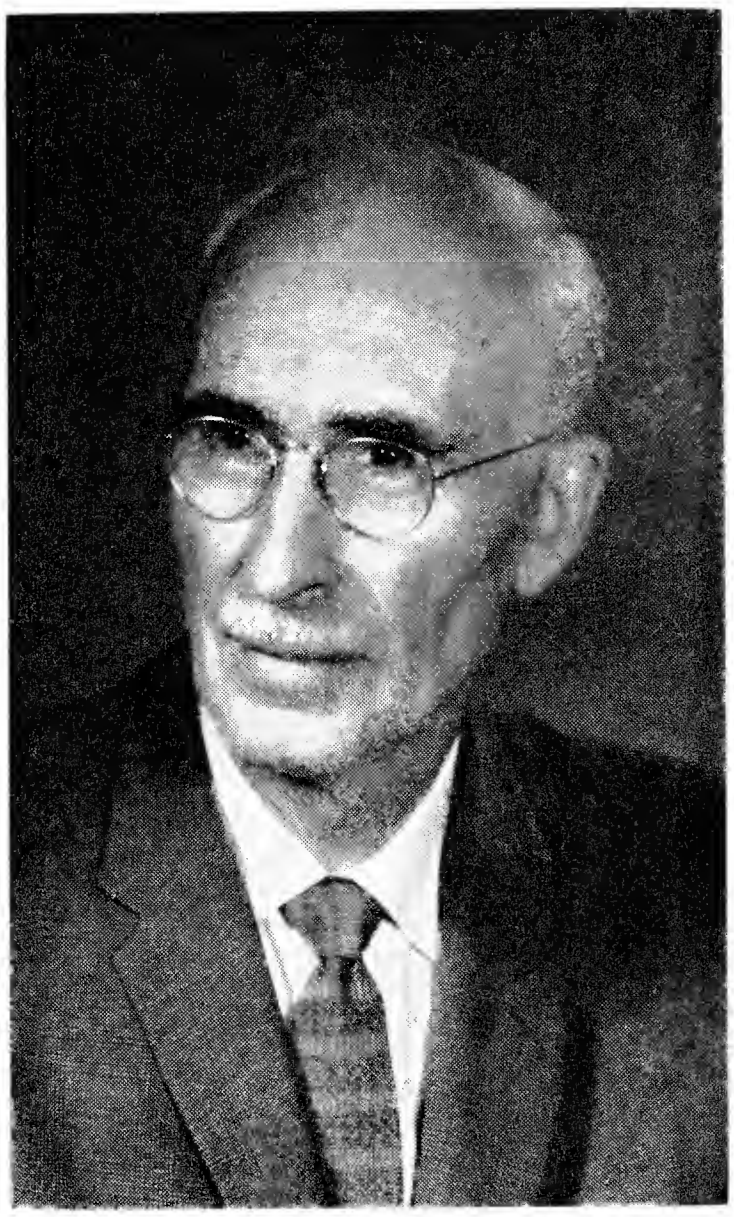
PRESIDENTIAL ADDRESS

THIS I WOULD LIKE TO KNOW—

WALTER B. WELCH
Southern Illinois University, Carbondale



WALTER B. WELCH
President, 1961-1962

At the 54th Annual Meeting of the Illinois State Academy of Science, the introduction for this address was sounded. Dean Hobart Heller at Eastern Illinois University, acting in the absence of President Quincy Doudna, said that there had been a number of well known scientists who, at one time or another during their careers, had been at Eastern as students or professors. The Botanists present thought of such as E. N. Transeau. He gave an address, as retiring president of the Botanical Society of America, under the title of "The Fifty Golden Years of Botany." It is the failing of retiring presidents to make speeches that act as summaries of a lifetime of activities in that president's field of endeavor, or a history of the organization being addressed. The history of the Illinois State Academy of Science is being written. It is not my desire to anticipate that work.

Those of us who are in the teaching of science use this method as an introduction to a science, or as we say "To give the historical prospective to our subject." This may be done so well and completely that the students get the idea that all the problems are solved, that all the answers are given, and they will turn away from science to other fields where there is still some of the unknown to be found. This is an overstatement and is not necessarily true of all sciences nor of any particular science but it may be true of a particular scientist in a particular science.

Part of the function of an instructor before a class should be to raise doubts and questions in the minds of his students as well as to give answers to questions and to solve problems. This asking of questions is the introduction to research. It was with this in mind that the title "This I Would Like To Know —" was chosen. It will be evident at once that this title is wrong and it should read "These I Would Like To Know—".

Some of you will remember that the 1955 Annual Meeting of this Academy was held at Southern Illinois University in what was then the new Life Science Building. Around that building were mounds of mud that the landscape architect had left. The remark was made that the architect was attempting to hasten organic evolution. When asked "How?" the answer was "By providing an environment that might be conducive for the development of mountain goats with webbed feet." A member of the staff of a sister science was heard to growl, "It would be well for him to stick to his own field." I shall try to heed that admonition.

What is hinted at here is that others of the biological sciences have advanced much farther in the explanations of the development of tissues and organs than have the plant sciences. These explanations cannot be applied to plants without extensive modifications. I shall try to stay with the study of plants.

The questions asked here are not especially new. Some of them were asked by the first persons who examined plants and plant structures. Some of the questions were "Where?," "When?," "How many?," and "How come?" or "Why?" The "where" and "when" have been rather well investigated and recorded. The "how many" is easily counted, analyzed, and recorded but the "how come" or "why" may still elude us.

To many students of the structure of plants, the idea that simplification or reduction of a structure, as an advance in the development of an organ or a plant, is presented. This idea is illustrated in reproductive organs, vegetative organs and in the number of chromosomes in the cell. One example might be the reduction in the number of neck canal cells of the archegonium as seen in such plants as those of the *Bryophyta*. The greater number of cells in the neck canal of the Mosses means that in this character the Mosses are more primitive than the Liverworts. How did the Mosses get the longer neck and greater number of neck canal cells? Those plant scientists who have proposed the theory that Mosses are more primitive than the Liverworts have had trouble with this. The Mosses could have, by reduction of numbers of cells, produced a neck and neck canal of the Liverworts but how did the Mosses get the greater number in the first place?

A similar situation is found in the theories that explain the structures of the stems of plants. We teach that those plants that have a reduction in the amount of secondary growth are more advanced in this characteristic than those plants which have a greater amount of secondary growth. The theories of

simplification and reduction of tissue or organs are rather well known but the enlargement of an organ or tissue, or the theory of accretion, is seldom expressed.

One of the usual ways in which to explain the larger structures is to say that over a great period of time these structures, organs, or tissues are built up. It does not take a student of the plants of the past very long to discover that the plants with the larger and more complicated structures, organs, or tissues had their origin about the same time as those with reduced structures. One attempt to review the information we have on the accretion theory was made by a member of the Illinois State Academy of Science, Wilson Stewart (1960). He proposed that more than one stem was involved in the development of the stems of some fossil plants. Several stems came together to make one stem with more than one stele. These separate stems might at first be just that, separate stems growing very close together. Later they might "fuse" making a stem with several steles. Still later the structure of the stele may be altered until only the vascular bundles are left and a stem appears with many vascular bundles in what is apparently only one stele. Thus the theories of simplification and reduction come into play. But first, the theory of accretion is necessary to get the larger structures that can be reduced. Other attempts should be made to account for the ideas of simple vs. complex or rather from the complex to the simple or reduced in plant structures.

The greater number of chromosomes per nucleus of the cells of some of the Ferns as compared with the numbers of chromosomes in the Angiosperms has caused wonderment. It has been proposed that there has been a doubling or at least an addition of chromosomes to build up a greater number, but here our timetable seems to be in reverse again. The plants with the higher number of chromosomes seem to have been the ancestors of the plants with the fewer chromosomes. How can a plant lose chromosomes without losing the genetic information necessary to keep it alive?

Techniques are now in use that will help us identify the chromosomes of different plants that had a common ancestry. The chromosome number, 256, of some of the Ferns seems to be out of line with the reduced number, 16, of some of the Angiosperms and they bear little similarity to the chromosomes of the Flowering Plants. Do the Ferns require so much more genetic information that they have to have so many more chromosomes than the so-called higher plants? Or will the size of the chromosome make up for the lower number in the Angiosperms?

"This I would like to know—" How does differentiation take place in two sister cells such that they produce different tissues or become a part of different tissues. The sister cells come from the same mother cell; presumably they have the same heritable characteristics. Some contemporary botanists theorize that there is enough genetic information in the make-up of the chromosomes to provide all the possible moro-

phological variations. This may be an oversimplification that will here lead us to obscure some of the details of differentiation. Would not both daughter cells of the same mother cell have the same genetic information under normal conditions? One cell may give rise to very different cells and tissues than its sister cell. Then is there some intrinsic factor which will cause a difference? We have not been able to show that they receive different chemicals from the environment, externally. It does not seem that the position of the cells can account for the difference.

Examples of the differences in cell behavior are pointed up in the work on Junipers by Margaret Kaeiser (1960), as reported in the Transactions of the Illinois State Academy of Science. Here not only were different tissues produced from the derivatives of the same mother cell but in different amounts.

As Kaeiser points out, some buds of a leafy shoot produce elongated stems and other produce the dwarf stems. Others have shown, in some plants, that the removal of the apical bud may cause the dwarf laterals to assume the characteristics of the bud that produces an elongated branch. Is there a reversal of genetic information here or will other intrinsic or extrinsic factors be responsible for this change? When will this reversibility cease? Is there, again, chemical or physical factors involved that we do not know?

The first person to work out a mathematical explanation of the arrangement of the leaves on a stem was Leonardo Da Vinci (Welch, 1933) over 400 years ago. He saw "where," "when," and "how many." But "why" he did not answer. Since Da Vinci's time others have found the phyllotaxy is a family characteristic and that it is transmitted from parent to offspring. This would indicate that genetic information is responsible for the arrangement of leaves on a stem. Much work has been done on many plants of many families with some clear results. We know what cells are involved with the first development of anything that looks like a leaf—the leaf primordium. But why these cells and not the cells next to them? Why these cells and not those that are 4 or 5 off to the right or left? Here again we may have to go beyond our ideas of what is inherited in order to explain these cell differences.

The work with vegetative buds has had its counterpart in work with flower buds. And right away we could ask the question — Why are flower buds ever produced? In this Academy Barbara Palser (1958) has presented several papers with her students. Here, it has been pointed out, there are great differences in the development of the cells that go through microsporogenesis and those that go through a megasporogenesis. Yet these cells had their inheritance from the same cells and tissues. These original tissues were developed from the same cells that produced the vegetative organs. How do these certain cells in the flowers of the Heath family differ from all other cells that these will produce microspore mother cells and megaspore mother cells but no other cells will

produce similar initials? The genetic information may be the same in all cells. Then is there some other factor necessary? Here again we ask is there an intrinsic factor involved? Is this factor in the cell itself or is it from surrounding cells?

Some research is being carried out by a member of this Academy to see if certain chemicals can be made to perform as a substitute for an intrinsic factor or, in this case, be an extrinsic factor. Are the growth regulating substances the excitants that will initiate morphogenesis in plant structures? The point is initiate. We know that the auxin related growth regulator substances will enhance the development but will they initiate the development of cells, tissues, or organs? This is one of the things this researcher is attempting to illustrate. He is using growth regulating, auxin-like chemicals on woody cuttings to determine what happens when adventitious roots are developed.

There has been some discussion between plant physiologists and morphologists as to whether the growth centers are already present or developed by the auxin related chemicals. There is no clear evidence one way or the other. If there was sufficient evidence, we would not have the question. The work cited may not answer the questions but this and other research may bring us nearer the answer.

"This I would like to know—" What initiates cell division? Many of the cells of the meristems of plants seem to have all that is necessary to support mitosis or for that matter — meiosis. There seems to be enough food. The structure of the nucleus and cytoplasm seem to be such that mitosis and cell division could take place. Then why don't these cells divide more often or sooner than they do? Some cells of a meristem have established a rhythm that has been recorded. Others have not or at least it is not reported. Is the rhythm or lack of rhythm determined by some chemical that needs to be brought in to stimulate the activity? There seems to be enough of all chemicals necessary including enough of the ribonucleic acid. There seems to be more than enough deoxynibonucleic acid present to provide for all the chromosome material needed. In fact for some theory-makers there seems to be too much DNA in the "resting cells."

Then why does the cell not divide sooner or more often? One of the popular explanations for such activities, control or rhythm, is that there is an inhibitor present. No activity can take place until this inhibitor is removed or inactivated.

A member of this Academy is attempting research on the process of mitosis to see if there is, indeed, an inhibitor present and if it is, can it be inactivated. There is some evidence that some chemicals are present in the "resting cell" that will disappear as the cell divides. Are these inhibiting substances? Attempts are now being made to make the suspected inhibitor disappear. If it can be made to disappear or be inactivated, then it will have to be determined if cell division is speeded up.

These are some of the things I would like to know. You may have

some of the answers; others will come as the result of research. And this research will be replaced by still further research.

The first requirement of this research should be an idea. The idea should be dealt with with imagination. Too often we are apt to let a piece of equipment do all the interpretation of the information gathered. Too often the measure of the stature of a man in the scientific community is the measure of the number of dollars he can bring in from outside foundations. Those who assign, assist, direct or otherwise encourage research should encourage the use of the idea equally, if not in greater measure, than the use of equipment.

Research will go on continually. Research is as much of a compromise as is the passing of time and it can't be stopped. If the philosopher can say "today is a compromise between yesterday and tomorrow," then we can paraphrase to say "we teach today what we did not know yesterday, only to have it disproved tomorrow." Such is our imperfect state of knowledge. We can hope that with the results of research we will teach fewer falsehoods tomorrow than we teach today.

Literature Cited

Kaeiser, Margaret. 1960. Shoot Apices in Two Hybrid Junipers. Trans. Ill. State Acad. Sci., 53:132-140.

Palsar, Barbara. 1958. Studies of Floral Morphology in the Ericales—IV, Observations on Three Members of the Gaultherieae. Trans. Ill. State Acad. Sci., 51:24-34.

Stewart, Wilson. 1960. More About the Origin of Vascular Plants. Plant Science Bul., 6: No. 2, p. 1-5.

Welch, Walter B. 1933. Leonardo Da Vinci's Study of Plant Form. The Resources of Leonardo Da Vinci (An Abstract) S.I.U. Press.

SOME COACTIONS OF CANADA GEESE AND SMALL MAMMALS

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Where Canada geese concentrate their feeding and resting activities, virtually all forage and seeds are consumed in a relatively few days; remaining vegetation is trampled to ground level or even into the ground. Because grazing geese tend to avoid or shy from roads, fence rows, field edges, or certain physical structures (Bell, 1957; Biehn, 1951; Helm, 1951; Washington State Game Department, 1953), the last available foods are found adjacent to these sites. On occasion, under extreme food shortages, these sites may be utilized by late winter; however, such is an exception. It appears that these feeding and resting activities of the geese might alter the availability of food and cover to small mammals so as to result in a reduction of rodent populations. To evaluate this and other coactions, a study of small mammals was conducted during the winter of 1961 by operating of traplines in wheat, pasture, and corn fields of the Union County Refuge. A similar agricultural area with little or no goose activity, approximately 10 miles north of the Refuge, was included for comparative studies.

The Union County Wildlife Refuge comprises 6,201 acres of bottomland 4 miles east of the Mississippi River and about 1 mile south of Ware. This sanctuary was originated in 1947 to provide a feeding and loafing area for part of the population of Canada geese, *Branta canadensis*, which winters in southern Illinois. The Refuge, as operated by the Illinois Department of Conservation, provides wheat, *Triticum aestivum*, corn, *Zea mays*, and pasture plants such as ladino clover, *Trifolium repens*, fescue grasses, *Festuca* spp., and orchard grass, *Dactylis glomerata*. Johnson grass, *Sorghum halopense*, common crab grass, *Digitaria sanguinalis*, and the panic grasses, *Panicum* spp. are common weeds in corn and pasture fields.

Trapping was initiated January 6 and terminated March 31, 1961. Hence, populations of small mammals were not studied prior to the arrival of geese in September nor after their departure in March. Museum special and regular mouse traps were utilized in determining the distribution and number of small mammals; a mixture of peanut butter and rolled oats was used as bait. In all areas sampled, intervals of 10 feet were maintained between stations; one trap was placed at each station. The straight-line method of trapping was used in Fields 1a and 3 through 9 (Table 1); grid trapping was employed in Fields 1b and 2. Fields 2, 5, and 7 were located near Wolf Lake, Illinois; the remaining fields including 8, which was subjected to

[1] Represents a contribution from Project No. 45, Cooperative Wildlife Research Laboratory.

TABLE 1. Results of Small Mammal Trapping in Agricultural Fields, Union County Wildlife Refuge and Private Property, Illinois, January-March, 1961.

Type of Field	Field Number	Number of trap Nights	Number Captures of Each Species				Total Captures of all Species	Percent Trapping Success
			Peromyscus maniculatus	P. *leucopus*	*Mus musculus*	*Microtus ochrogaster*		
Wheat								
Grazed	1a	1,798	23	0	10	15	48	2.7
(Refuge)	1b	3,398	5	0	15	12	32	0.9
	3	1,060	7	0	2	1	10	0.9
Totals		6,256	35	0	27	28	90	1.4
Ungrazed	2	750	8	10	15	7	40	5.3
(Control)		.....	..	..	..	..	..	...
TOTALS		7,006	43	10	42	35	130	1.9
Corn								
Utilized	4	542	12	0	9	0	21	3.9
(Refuge)	6	696	6	0	0	0	6	0.9
Totals		1,238	18	0	9	0	27	2.2
Nonutilized	5	542	0	0	9	0	9	1.7
(Control)	7	698	1	0	4	0	5	0.7
Totals		1,240	1	0	13	0	14	1.1
TOTALS		2,478	19	0	22	0	41	1.7

Type of Field	Field Number	Number of trap Nights	Number Captures of Each Species				Total Captures of all Species	Percent Trapping Success
			Peromyscus maniculatus	P. *leucopus*	*Mus musculus*	*Microtus ochrogaster*		
Pasture								
Grazed								
(Refuge)	9	900	16	0	0	4	20	2.2
Ungrazed								
(Refuge)	8	900	3	0	0	0	3	0.3
TOTALS		1,800	19	0	0	4	23	1.3
All Utilized		8,394	69	0	36	32	137	1.6
All Nonutilized		2,890	12	10	28	7	57	2.0
GRAND TOTALS		11,284	81	10	64	39	194	1.7

little use by geese, were within the confines of the Refuge.

Results and Discussion

Trapping success during the three months was low as 11,284 trap nights yielded 194 captures of small mammals, a success of 1.7 per cent (Table 1). Four species of mice were represented in the captures for the three types of fields (Table 1). *Peromyscus maniculatus* (81) was the most abundant and widely distributed, making use of all but one control harvested cornfield. *Mus musculus* (64) ranked second although it was not represented in the captures in pasture or one field of goose-harvested corn. *Microtus ochrogaster* (39), third most abundant, was not recorded in cornfields or ungrazed pasture. *P. leucopus* (10) yielded less than 5 per cent of the catch and was taken in an ungrazed wheat field.

In Field 1b, a lightly grazed strip of wheat 6 inches in height extended from a roadside 30 feet into the field; in this area 23 of a total of 32 captures for the entire field were recorded. In Field 2, where wheat was 12 inches in height throughout, 9 of a total of 40 captures were recorded in a strip 30 feet wide, parallel to the edge of the field. Of 12 captures of *Microtus ochrogaster* in Field 1b, 11 were recorded in the lightly-grazed strip of wheat at the field border; 11 of 15 *Mus* were captured in that section; and, of five captures of *P. maniculatus*, one was taken from that area. *P. leucopus* was collected only in Field 2.

In Field 3, a "no trespassing" sign was located 50 feet from a field corner bordered by the junction of two roads. The only *Microtus* taken in the field and one of two *Mus* were captured in this corner where the wheat was 8 inches high; the other *Mus* was taken near the corner. All *P. maniculatus* were collected outside this area in sections where grazing was more intense; two were taken in areas of bare ground.

In Field 1a, *Microtus* were caught only in the row of traps set 10 feet from the field border in a lightly grazed strip of wheat (6 inches high) which extended from a roadside 20 feet into the field; most of the *Mus* and a few *P. maniculatus* were taken in this area. Some *Mus* and the majority of *P. maniculatus* were collected 150 feet from the field edge where the wheat was 1 inch high.

Microtus seemed to show the most direct relationship to goose use of wheat as 27 of 28 specimens were taken in lightly-grazed areas in which the wheat was 6 inches or more in height. Although *Mus* was taken in heavily-grazed sections, it seemed to prefer taller, denser cover, as 20 of 27 specimens were taken in lightly-grazed areas. *P. maniculatus* was least affected by grazing; 29 of 35 captures were recorded where goose utilization was most intense.

Although direct evidence was lacking, some competition probably existed among small mammals for the greater supply of food and cover present in areas of light grazing. *P. maniculatus,* although found mainly in areas which lacked cover, were apparently able to compete successfully with other small mammals where heavy cover and an abundance of food were available (Table 1, Field 2). Linduska (1946) found

that numbers of *P. maniculatus* were somewhat higher toward the center of cultivated fields than nearer field edges which were adjacent to heavy fencerow cover. Johnson (1926) noted that this species was characteristically an animal of cultivated fields and was not found in relatively undisturbed areas which were inhabited by *Microtus*. The possibility that at the Union County Refuge *P. maniculatus* might have been foraging into denuded areas from living quarters in areas of light grazing was not substantiated by trapping data.

The majority of captures of *P. leucopus* in Field 2 (Table 1) was juveniles which ranged farther into the field than did the adults. Presence of a shrubby area at the field border probably accounted for the occurrence of this species. It has been suggested that *P. leucopus* enter open fields due to population pressure in adjacent woods (Blair, 1940).

All cornfields sampled were picked mechanically, much grain being lost during the harvesting process. Waste grain was abundant in the control fields as entire ears and individual grains were observed. On the Refuge, geese were thorough in gleaning the fields as no grain was found, although cobs were plentiful. Only *P. maniculatus* and *Mus* were captured, the former being most abundant in cornfields on the Refuge and the latter in control fields.

Canada geese have been found to eat the seeds and, in some cases, the dried stems of weeds which are found in cultivated fields (Bell, 1957; Helm, 1951). Thus, geese probably not only compete with small mammals for cultivated crops, but also for most other foods which are acceptable to the rodents; conversely, droppings of geese might have constituted a source of food if the rodents were coprophagous.

In cornfields on the control areas, a large quantity and variety of food were available to small mammals including corn, weed seeds, and a small amount of green vegetation. As a result, the rodents were possibly not readily attracted by artificial food used as bait in the traps. This may have been responsible for the low catch in control fields and the relatively higher catch in goose-used acreages.

Pastures contained many of the weeds found in cornfields; and, as in cornfields, geese would be expected to be in direct competition with rodents. Field 9 (Table 1) was perhaps the most heavily goose-utilized area at the Refuge; cover and food in particular were scarce. However, several litters of *P. maniculatus* and one litter of *Microtus* were brought off in this area during the latter part of March. This indicated that some rodents not only were able to survive a period of apparent stress but were able to reproduce.

Microtus were taken only at the border of Field 9 near a ditch and heavily traveled road where cover was heavier than in the rest of the field; also, some green vegetation was present. This situation seems similar to that Martin (1956) reported where *Microtus* were apparently absent in pasture which was over-grazed by cattle but occupied a nearby ungrazed area. As in wheat fields on the Refuge, a strip at the edge of Field 9 may have served as a sanctuary for *Microtus*

as little goose activity occurred there. This restriction of *Microtus* to a small area not utilized by geese indicated the importance of heavy cover. Although adequate cover is an important habitat requirement of this species, Dice (1922) concluded that sources of food—green vegetation and roots or tubers—are more necessary.

Fields 1a, 1b, and 3 each exceeded 100 acres in size, but suitable habitat available to *Microtus* was limited to a few acres of lightly grazed wheat. If it can be assumed that *Microtus* would occupy the entire area of each field if grazing were lacking, then it can also be assumed that *Microtus* populations were reduced to a great extent. There is little evidence to suggest that *P. maniculatus* and *Mus* populations were greatly reduced in heavily used fields.

When cattle were removed from an over-grazed pasture in Kansas, succession from coarse weeds to succulent grasses progressed; and, as an apparent result, *Microtus* increased from a very low population to a level of abundance in approximately 2 years (Martin, 1956). In fields of intense goose utilization at the Union County Wildlife Refuge, the ecological situation and time factor are somewhat different from that described in the above study. The effects of geese are temporary as they are absent during summer and most of spring when vegetative growth is greatest. In addition, the food supply of all small mammals is renewed each year by planting and growth of weed species; thus rodent numbers probably increase to a normal level as habitat restrictions terminate shortly after the geese migrate north and the vegetation is able to resume normal growth.

Summary

Species type and population level of rodents both seemed to show a relationship to the feeding activities of the Canada geese. However, this relationship could not readily be diagnosed as a direct result of goose utilization and destruction of cover. Land use and management practices of the previous summer and fall determined the kinds and amounts of cover and food available to the small rodents irrespective of the presence of the geese. Hence, differential degrees of effectiveness of goose utilization in enhancing or discouraging the occurrence of a given species of mouse could not be established with finality. Further, lack of data on stored food supplies as noted for several rodents by Wood (1910), Fisher (1945), and Kennicott (1857), prohibited a complete understanding of the food complex for each species captured.

In many cases the presence or absence of a given species of mouse showed a relationship to the nature of habitats immediately adjacent to areas which were grazed heavily. When grazed areas were bordered by roadsides or other natural field boundaries, the number of captures, distribution, and species of rodents seemed to reflect this. Frequently, due to the avoidance response of geese to field edges or isolated structures in a field, a lightly grazed or non-grazed spot or strip of wheat or pasture was present. The pres-

ence or absence of such areas was apparent in the trapping success of most species of mice.

In wheat fields where *Microtus* were restricted to lightly grazed areas, the depression on population size was most pronounced. On the other hand, the majority of captures of *P. maniculatus* was recorded in those areas of wheat which were heavily grazed by the geese; *Mus* usually preferred areas of light grazing. Of two pastures and four cornfields sampled, *Microtus* were taken only at the lightly-used edge of a pasture which provided heavy cover and green vegetation. In both pastures and cornfields, a greater number of captures was recorded from heavily-utilized fields than in control areas which were subjected to little or no use by the geese. The great quantity and variety of food available to the small mammals probably reduced the attractiveness of bait in control fields.

In a pasture which showed greater goose use than any other fields trapped, *P. maniculatus* and *Microtus* were able to bring off litters in late March. However, populations of rodents in all utilized fields were probably reduced.

Literature Cited

Bell, R. Q. 1957. Food coactions of Canada geese, *Branta canadensis interior*, Todd, in southern Illinois. Unpublished M. A. thesis, Southern Ill. Univ. Libr., Carbondale, Ill., 89 pp.

Biehn, E. R. 1951. Crop damage by wildlife in California with special emphasis on deer and waterfowl. Calif. Fish and Game Bul., 5:1-71.

Blair, W. F. 1940. A study of prairie deer mouse populations in southern Michigan, Amer. Midl. Nat., 24:273-305.

Dice, L. R. 1922. Some factors affecting the distribution of the prairie vole, forest deer mouse and prairie deer mouse. Ecology, 3:29-47.

Fisher, H. J. 1945. Notes on voles in central Missouri. Jour. Mammal., 26:435-37.

Helm, L. G. 1951. Effects of Canada geese on crops and soils in central Missouri. Unpublished M. A. thesis, Univ. Mo. Libr., Columbia, Mo., 107 pp.

Johnson, M. S. 1926. Activity and distribution of certain wild mice in relation to the biotic community. Jour. Mammal., 7:245-77.

Kennicott, R. 1857. The quadruped of Illinois injurious and beneficial to the farmer. Trans. Ill. State Agr. Soc., 2:615-84.

Linduska, J. P. 1946. Edge effect as it applies to small mammals on southern Michigan farmland. Trans. N. Amer. Wildl. Conf., 11:200-204.

Martin, E. P. 1956. A population study of the prairie vole (*Microtus ochrogaster*) in northeastern Kansas. Univ. Kansas Mus. Nat. Hist. Publ., 8:361-416.

Washington State Game Department. 1953. Do wild geese injure wheat crops? Wash. State Game Bul., 5 (3): 12.

Wood, F. E. 1910. Mammals of Champaign County. Ill. State Lab. Nat. Hist. Bul., 8:501-613.

DIETARY PATTERN OF THE VIRGINIA OPOSSUM, *DIDELPHIS MARSUPIALIS VIRGINIANUS* KERR, LATE SUMMER-WINTER, SOUTHERN ILLINOIS

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The opossum (*Didelphis marsupialis virginianus* Kerr) is one of the most common furbearers in Illinois, and is especially abundant in the southern one-third of the State. Because of its wide range of tolerance, omnivorous diet, and high reproductive rate, this marsupial shows general population increases and continuing widening range, utilizing previously unoccupied areas not only in the United States but in Canada as well. Success among the mammalian fauna is further enhanced by its low-valued pelt, expanding urban developments, and decrease of emphasis on it as a food item or for sport hunting.

This study of the opossum was undertaken to (1) ascertain what food items are utilized and the frequency of occurrence and volume of each, (2) relate food utilization with seasons, and (3) evaluate this mammal as a predator. Although the literature failed to reveal a detailed study of the diet of the opossum in Illinois, several investigations of its food habits have been published for other states (Reynolds, 1945; Hamilton, 1958; Taube, 1947; Wiseman and Hendrickson, 1950; Sandidge, 1953; Lay, 1942; Wheeler, 1939; and Llewellyn and Uhler, 1952).

Standard laboratory techniques were utilized in analyzing digestive tracts and in identifying their contents. The volume of each item of food was determined by water displacement; frequency of occurrence was computed on a percentage basis. For standardization of nomenclature of food items, Fernald (1950) was used for plants, Hall and Kelson (1959) for mammals, American Ornithologists' Union (1957) for birds, Conant (1958) for reptiles and amphibians, and Comstock (1947) for insects.

Mr. Erwin Pearson, formerly Adjunct Research Associate with the Laboratory, supplied many of the opossums. This paper represents a contribution from Projects No. 45 and 52, Cooperative Wildlife Research Laboratory, Southern Illinois University, and is abridged from a thesis submitted in partial fulfillment of the requirements for the Master of Arts degree in Zoology. The data contained herein, and the preparation of this paper are in no way associated with the U. S. Bureau of Sport Fisheries and Wildlife.

Results

The digestive tracts from 131 opossums collected in seven southern Illinois counties from August, 1958, through February, 1960, were used in this investigation. Number of samples according to month was as follows: January (11), February

TABLE 1. Major Food Items Occurring in Digestive Tracts of 131 Opossums, Southern Illinois, 1958-1960.

Food Item	Per Cent Volume	Per Cent Frequency of Occurrence
ANIMAL FOODS	76.2	100.0
Mammals	48.7	76.3
Opossum	16.3	52.7
Cottontail	14.7	15.3
Prairie Vole	6.4	5.3
Gray Fox	2.8	3.1
Short-tailed Shrew	1.8	4.6
Raccoon	1.7	1.5
Norway Rat	1.5	0.8
Eastern Mole	1.3	0.8
Deer Mice	1.0	3.1
Striped Skunk	0.5	3.1
Pine Vole	0.5	1.5
Other Mammals	0.2	....
Birds	14.5	19.1
Domestic Chicken	7.1	4.6
Grackle	4.7	2.3
Towhee	1.3	0.8
Meadowlark	1.1	3.1
Other Birds	0.3	....
Reptiles	1.6	14.5
Blue Racer	0.7	4.6
Other Reptiles	0.9	....
Amphibians	3.0	5.3
Frogs	2.5	3.8
Toads	0.5	1.5
Fishes	0.1	1.5
Unidentified Scales		
Insects	6.3	93.1
Scarabaeidae Larvae	2.0	11.5
Short-horned Grasshoppers	1.5	54.2
Unidentified Lepidoptera Larvae	0.9	9.2
Other Insects	1.9	....
Other Invertebrates	1.9	....
Earthworms	1.3	3.8
Snails	0.5	31.3
Miscellaneous Invertebrates	0.1	....
Undetermined Animal Materials	0.1	2.3
PLANT FOODS	23.8	100.0
Persimmon	8.1	21.4
Pokeberry	5.1	25.2
Grapes	1.8	11.5
Tree Leaf Fragments	1.3	87.0
Corn	1.1	3.1
Gramineae Leaves and Stems	0.9	71.0
Plums (*Prunus* spp.)	0.9	3.1
Nightshade (*Solanum* sp.)	0.9	25.2
Unidentified Fleshy Fruits	0.9	3.8
Bark and Woody Twigs	0.8	37.4
Unidentified Seeds and Seed Pods	0.7	9.2
Other Plant Foods	1.3	....

(16), August (12), September (22), October (29), November (35), and December (6). One hundred and eleven individuals were taken by trapping, 4 by hunting, and 16 as DOR.

A total of 75 animal and 66 plant foods were recorded;[1] of these, only 24 animal and 11 plant foods individually constituted 0.5% or more by volume (Table 1). Animal foods yielded 76.2% of the total volume and plant foods 23.8%; both groups appeared in 100% of the tracts. Four occurrences of miscellaneous items (string, sacking material, cotton filter) were recorded; these were believed to have been ingested accidentally.

Animal Foods. Mammals represented the most important group of foods, constituting 48.7% of the total volume (Table 1). This is in close agreement with other studies with the exception of Lay (1942) who reported mammals yielding 7% by volume; however, his sample was small (16 stomachs) and represented a single month (September).

The highest ranking food item volumetrically (16.3%) was opossum (Table 1), suggesting considerable evidence of cannibalism. Although remains of opossums appeared in 52.7% of the tracts, only a small percentage of the occurrences was considered to be actual food items as hair and nails were the principle evidences; these probably were ingested during preening or trap-fighting. Four stomachs, which were filled with remains of opossum, somewhat distorted the volumetric value for this food item. The majority of previous records of cannibalism were among captive animals (Pray, 1921; Seton, 1929; Raven, 1929; Wheeler, 1939; Wood, 1954). For wild-living forms Reynolds (1945) and Sandidge (1953) reported that volumetrically, opossum contributed 4.9% and 10.9%, respectively.

Cottontail rabbit (*Sylvilagus floridanus*) was the second most important food consumed, yielding 14.7% by volume and occurring in 15.3% of the tracts. In Kansas (Sandidge, 1953), Missouri (Reynolds, 1945) and Michigan (Taube, 1947), cottontail was the primary food.

The prairie vole (*Microtus ochrogaster*) represented the third ranking mammalian food item and was fifth among all foods. It is noteworthy that this species constituted 6.4% by volume whereas deer mice (*Peromyscus* sp.) comprised only 1.0%.

Large mammals did not contribute a significant portion of the diet as by volume gray fox (*Urocyon cinereoargenteus*) furnished 2.8%, raccoon (*Procyon lotor*) 1.7%, and striped skunk (*Mephitis mephitis*) 0.5%.

Short-tailed shrews (*Blarina brevicauda*) ranked fifth and eastern moles (*Scalopus aquaticus*) eighth among mammalian foods; collectively they represented 3.1% of the total volume (Table 1). Hamilton (1958) recorded insectivores from 46 of 461 stomachs. Opossums apparently do not share the distaste of the red fox (*Vulpes fulva*) for this group of mammals (Murie, 1936; Scott and Klimstra, 1955).

Domestic chicken (*Gallus gallus*)

[1] For detailed tabular data consult thesis by senior author on file in Library, Southern Illinois Universty, Carbondale.

comprised 7.1% of the volume of all foods taken and ranked fourth. It is doubtful if this represented actual depredation on poultry flocks; more likely it reflected availability of carrion.

Among other birds, the grackle (*Quiscalus* sp.) was taken on three occasions (ranked seventh by volume), meadowlark (*Sturnella magna*) four times, domestic pigeon (*Columbia livia*) twice, and towhee (*Pipilo erythrophthalmus*), junco (*Junco hyemalis*), cardinal (*Richmondena cardinalis*), and carolina wren (*Thryothorus ludovicianus*) once each. Tremendous numbers of grackles winter in this region, and in localized situations dead grackles could be one of the most available foods, especially in roosting areas.

Reptiles occurred in 14.5% of the tracts, but were significant only during late summer; only sporadic occurrences were recorded throughout the remainder of the study period. The blue racer (*Coluber constrictor*) was the most important reptile, constituting 0.7% of the total volume.

Frogs (*Rana* sp.) were taken on five occasions and constituted 2.5% by volume. Toads (*Bufo* sp.) were less important, appearing in two digestive tracts and comprising 0.5% of the total volume.

Insect remains appeared in 93.1% of the digestive tracts, but constituted only 6.3% of the total volume (Table 1). Larvae were taken in considerable numbers, possibly being more desirable and vulnerable than adults. Reynolds (1945) reported that insects comprised 34.2% by volume December through May; Wheeler (1939) found that insects furnished 60.3% of the volume for 95 stomachs collected throughout the year; Sandidge (1953) noted that insects comprised 42.7% by volume in 60 digestive tracts taken from September through March. In contrast, Taube (1947), found 6% of the diet during September-December to be insects while Hamilton (1958) reported 7.9% of the total volume of 461 stomachs collected throughout the year.

The larvae of scarabaeid beetles (Scarabaeidae), the most important insect representative in the current study, constituted 2.0% of the total volume and showed a frequency of 11.5%. Although short-horned grasshoppers (Locustidae) occurred frequently (54.2%), they constituted only 1.5% volumetrically. Undetermined lepidopterous larvae had a frequency of 9.2%; no adults were recorded.

Plant Foods. Persimmon (*Diospryos virginiana*), which was the most utilized plant food, ranked third among all foods, comprising 8.1% of the total volume (Table 1). Pokeberry (*Phytolacca americana*) occurred in 25.2% of the tracts and furnished 5.1% of the total volume, ranking as the sixth most important food. Various other fleshy fruits constituted 4.9% of the total volume. Wild grapes (*Vitis* spp.) were eaten, but the volume furnished was relatively low (1.8%).

Dried fragments of tree leaves appeared in 87.0% of the tracts while bark and twigs appeared in 37.4%; this probably did not constitute important food. The majority of leaves were believed ingested accidentally during feeding activities on

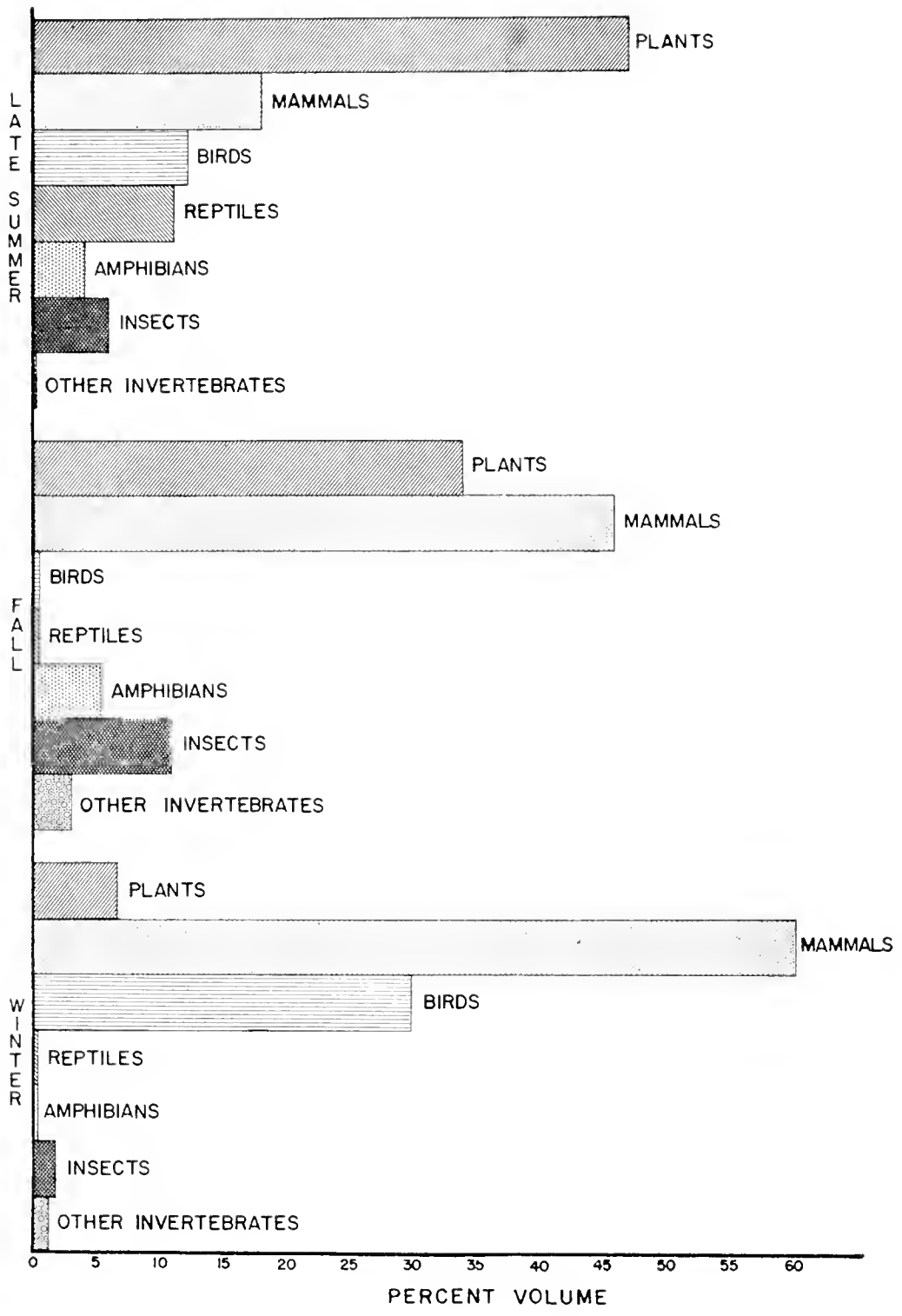

FIG. 1 Seasonal trends in the utilization of major food groups by opossums, southern Illinois, 1958-1960.

ground dwelling insects, snails, etc. Smith (1941) observed opossums to place leaves in their mouth during nest building activities which possibly accounts for the appearance of small quantities of leaves. Also, animals under the stress of being steel-trapped have been observed to ingest leaves, sticks, etc.

Kernels of corn (*Zea mays*) comprised 1.1% of the total volume (Table 2), and had a low frequency of occurrence (3.1%).

Seasonal Trends. In an effort to evaluate seasonal aspects of the opossum's diet, all digestive tracts were categorized into late summer (August and September), fall (Oc-

tober and November), or winter (December, January and February); 34, 64 and 33 samples were available, respectively, for each season.

Marked changes were noted in the seasonal utilization of plant and animal foods (Fig. 1). The volume of animal materials increased from 52.2% during late summer to 93.4% in winter; the importance of plant foods diminished in almost exact proportion.

Noticeable seasonal trends in the consumption of the various general food groups were also noted. The appearance of mammalian foods in the diet increased by over 300% between late summer and winter. As the variety of available foods decreased with the advent of severe weather, opossums possibly resorted more frequently to mammalian carrion. This is suggested by the marked increase in utilization of large forms such as gray fox, striped skunk, raccoon, woodchuck (*Marmota monax*), and opossum as the season progressed. Cottontail appeared infrequently during warm weather, but a major increase in utilization occurred with the onset of colder temperature and the beginning of the hunting season. The decline in consumption of cottontail during the winter period might be indicative of reduced cottontail populations.

Small mammals would tend to become more vulnerable to predation as the vegetative cover is reduced and they are exposed when in quest of food. Such is suggested by the utilization of prairie voles which showed an increase from 2.5% in the summer to 14.0% during the winter; however, predilection and reduced availability of other foods are probably reflected as well.

Birds furnished 12.3% of the total volume during August and September, but their use dropped to virtually zero in the fall. With the advent of cold weather and probable increased avian winter mortality, utilization of birds increased to 29.8% by volume; over four-fifths of this total was domestic chicken and grackle.

Reptiles appeared most frequently during mild weather with seven species of snakes and one species of turtle being recorded. The relative importance of reptiles decreased as low temperatures reduced the activity of these cold-blooded forms; three occurrences were noted in the fall sample and two in winter. Amphibians showed a similar pattern as they comprised 4.0%, 5.4%, and 0.2% of the volume for late summer, fall, and winter, respectively.

The volumetric importance of insects varied between the seasons. During late summer they furnished 5.9% of the total volume but had a 97.1% frequency of occurrence; in fall the volume was 10.9% and frequency 96.9% and in winter these measurements were 1.8% and 78.8%, respectively.

In decreasing order of importance by volume, short-horned grasshoppers, scarabaeid larvae, adult ground beetles, and larval ground beetles were the chief insect items identified in late summer tracts. Scarabaeid larvae and short-horned grasshoppers made up over two-thirds of the total insect volume for fall. The relative importance of insects sharply decreased with the onset of lowered

temperatures during winter; lepidopterous larvae constituted over 80% of all insect materials recorded for this period. By volume and by frequency of occurrence, various Hemiptera were next in importance. Short-horned grasshoppers, an important food item through fall, appeared in almost one-fourth of the winter tracts, but constituted only a trace by volume.

Volumetrically, Gramineae was the leading plant family consumed during late summer; corn was the most important species. The amount of grasses consumed diminished markedly in October and November, but increased noticeably during winter; corn was the most prevalent representative.

The utilization of fleshy fruits reflected strongly the time of ripening. Grapes were the second most important plant food in late summer; utilization remained fairly constant in fall, but declined sharply during winter. Persimmons were heavily utilized when present; the volumetric importance varied from 5.1% in late summer, 15.4% in fall, to 1.4% during winter. Fruits of this species normally drop when ripe, and would thus be most available in late fall. Although opossums are adept climbers, it is believed that they avoid doing so if possible, and probably prefer to eat persimmons on the ground; no green fruits were noted.

By volume, pokeberry was relatively important in late summer (6.0%) and fall (9.8%). Field observations indicate that the berries shrivel and dry with the onset of low temperatures, and they probably lose their appeal as a food item; this fruit was entirely absent in winter.

Discussion

Opossums, like many predatory animals, are opportunists in the procurement of food as they probably use the most readily available, acceptable foods. Certain food preferences seem to be reflected by the preponderance of particular items; however, selectivity is probably geared to restrictions imposed by season, physical ability, familiarity, and predilection (Scott and Klimstra, 1955).

The consumption of carrion was more pronounced with the advent of winter and the subsequent reduced availability of favored foods. However, it was difficult to accurately determine the percentage of the diet which resulted from carrion. Sandidge (1953) suggested that cottontail, muskrat, and opossum remains reflected carrion feeding because of the association of silphid beetles (Silphidae) in 12 of 19 occurrences of these mammals. Silphid beetles appeared in two tracts collected in September and November in southern Illinois; one contained cottontail remains, but the other only insect fragments. The conclusion of Wheeler (1939), who felt that silphid beetles were taken too promiscuously to be an accurate indicator of carrion feeding activities, seems quite logical. In the current study Muscidae larvae appeared in several tracts, but were not always associated with carrion. Seventy-five fly larvae were recorded from a single stomach which contained only insect and plant materials, suggesting that

the larvae were taken as a food and not secondarily with carrion. Hamilton (1958) postulated that opossums may consume copious quantities of fly larvae when available, disregarding the carrion on which the larvae might be feeding.

It seems possible that prairie voles are more vulnerable to predation or are more preferred by the opossum than are deer mice; most trapping studies of the Cooperative Wildlife Research Laboratory show the latter forms much the more numerous. The home ranges of opossums in southern Illinois normally encompass habitats frequented by both of these mice. The relative abundance of pine voles (*Pitymys pinetorum*), which is quite low in relation to prairie voles and deer mice, is reflected in that the former appeared only twice. Because pine voles and prairie voles inhabit like habitats and have similar habits, their vulnerability as prey should be approximately the same. The use of large mammals probably resulted from carrion as it is doubtful if an opossum could subdue a healthy, adult animal of these species. A lead shot pellet noted in one stomach which contained gray fox suggested that hunting injuries might have been the actual cause of death. A low frequency of occurrence indicates that large mammals were chance items in the diet.

It is noteworthy that meadowlarks or other ground nesting and roosting species were not taken more frequently. This suggests that opossums may lack the agility to be an efficient predator on wild birds, even ground nesters. This is borne out by the fact that the remains of nondomestic birds were recorded from only 17 digestive tracts.

Results indicated that reptiles were an acceptable item when available, and the species taken reflects the diverse habitat frequented by the opossum. Some snakes were probably picked up as road kills, but the opossum is capable of capturing snakes of considerable size (Lewis, 1929).

Earthworms (*Lumbricus* sp.) were unimportant in this study as they appeared in only five tracts, yielding 1.3% by volume. The consumption of this invertebrate seems to be a regional variable in regard to importance in the diet. Dexter (1951) found that earthworms comprised 15.3% volumetrically of 13 opossums collected in Northeastern Ohio during the winter. Hamilton (1958) reported that earthworms constituted 10.3% of the total volume in New York. Michigan studies indicated that earthworms comprised about 8.0% of the total volume (Taube, 1947).

Insects present an example of the fallacy of relying entirely on per cent volume as a basis for rating foods in dietary studies. These invertebrates ranked low volumetrically (6.3%) in the current study (Table 1), but occurred in 93.1% of the tracts examined; this possibly reflected some predilection. Conversely, the high frequency of occurrence and low volume furnished by insects may reflect in some cases chance or promiscuous feeding habits. This proposition would account for some of the incongruous values obtained for frequency of occur-

rence and per cent volume in this study.

The majority of plant foods recorded were available only during restricted seasons, but were heavily utilized at such times as they were present. This availability-consumption relationship is best illustrated by the example of pokeberry. Pokeberry fruits mature early in September in this area and remain available to opossums for an extended period. The tendency of pokeberry stems to bend and break makes the terminal fruiting heads available at a height conducive to feeding by the opossum. Dried fruits frequently adhere to the plant as late as March, but these were seemingly not as palatable to the animals as the juicy berries.

It is surprising that there was not greater utilization of corn in view of the abundance of this plant in southern Illinois. Hartman (1952) stated that opossums may procure corn in the manner of raccoons, i.e., by pulling up the seedling corn. Hamilton (1943) suggested that corn in the milk stage is a favorite food of opossums, and Reynolds (1945) reported corn as comprising 7.3% of the opossum diet. Wiseman and Hendrickson (1950) noted its occurrence in 46 of 87 scats collected in Iowa.

Grasses (Gramineae), other than corn, were recorded in 71% of the tracts, but in most cases probably reflect accidental ingestion or food of secondary origin. Leaves and stems made up the greater part of the volume, although 18 species of seeds were recorded. Some grasses are probably ingested as the opossum feeds on certain insects, particularly grasshoppers which commonly rest on this type of vegetation. Vegetative material or seeds of grasses were found in all tracts containing prairie voles, pine voles, or deer mice, possibly reflecting secondary ingestion.

Results indicate that predation by opossums during the period covered by this study was probably not an important influence on populations of game species. Of the major game animals found in southern Illinois, only the cottontail formed a significant part of the opossum's diet. Bobwhites (*Colinus virginianus*), tree squirrels (*Sciurus* sp.), white-tailed deer (*Odocoileus virginianus*), and ducks and geese (Anseriiformes) were not recorded from digestive tracts examined.

Probably a portion of the cottontail remains reflected actual opossum kills; but, there is a strong possibility that the larger percentage represented rabbits killed on highways or by hunters, or those deceased through natural causes. Hamilton (1958) proposed that opossums are capable of killing cottontails in their dens during winter; he reported five instances of predation by opossums on nestling rabbits. Unfortunately, the current study did not include sufficient quantities of tracts from the peak of the cottontail breeding season to determine the effects of predation on the young.

The absence of quail in the diet of opossums is an interesting facet. Field observations indicate that predation by various mammalian forms on quail nests is extensive, and opossums probably contribute to these

losses. There is a considerable difference of opinion as to the extent of opossum predation on nesting birds; Wheeler (1939) found that they were not destructive in this regard, but Roberts and Early (1952) felt that high opossum populations associated with concentrations of ring-necked pheasant (*Phasianus colchicus*) or rabbit nests might prove to be detrimental to these game species. Allen (1940) reported that in Michigan less than 5% of the nesting losses of ducks and pheasants were caused by opossums, but pointed out that opossum populations were low during the investigations.

Summary

Digestive tracts from 131 opossums, taken from August 1, 1958-March 1, 1960, in seven southern Illinois counties, were examined; all tracts contained food. Three seasons were represented; late summer (August and September): fall (October and November); winter (December, January, and February).

Animal materials made up 76.2% of the total food volume, and plant materials 23.8%. Both major food groups appeared in all of the tracts. Seventy-five animal and 66 plant foods were recorded. The ten most important foods by per cent volume were opossum, 16.3; cottontail, 14.7; persimmon, 8.1; domestic chicken, 7.1; prairie vole, 6.4; pokeberry, 5.1; grackle, 4.7; gray fox, 2.8; frogs, 2.5; and scarabaeid larvae, 2.0. According to per cent frequency of occurrence the ten top-ranking foods were grasses, 82.4; short-horned grasshoppers, 54.2; opossum, 52.7; ground beetles, 38.9; snails, 31.3; pokeberry, 25.2; nightshade, 25.2; stinkbugs, 22.9; persimmon, 21.4; and cottontail, 15.3.

Noticeable variations in the utilization of foods seemed to reflect seasonal availability. The most marked variation was a steady decrease in consumption of plant materials from fall through winter, and an increase in utilization of mammalian foods during the same period.

Predatory activities apparently do not have a strong adverse effect on game populations. However, predation on cottontails might, on occasion, constitute a minor curb on populations of this species.

Literature Cited

Allen, D. L. 1940. Nobody loves the 'possum. Michigan Cons., 9 (6):5, 10.

American Ornithologists' Union. 1957. Check-list of North American birds. 5th ed., Lord Baltimore Press, Baltimore. 691 pp.

Comstock, J. H. 1947. An introduction to entomology. Comstock Publ. Co., Ithaca, New York, 1064 pp.

Conant, R. 1958. A field guide to reptiles and amphibians. Houghton Mifflin Co., Boston, 366 pp.

Dexter, R. W. 1951. Earthworms in the winter diet of the opossum and raccoon. J. Mammal. 32 (4): 464.

Fernald, M. L. 1950. Gray's manual of botany. 8th ed. American Book Co., New York, 1632 pp.

Hall, E. R. and K. R. Kelson. 1959. The mammals of North America. Ronald Press Co., New York, vol. 1, 546 pp.

Hamilton, W. J., Jr. 1943. The mammals of eastern United States. Comstock Publ. Co., Ithaca, New York, 432 pp.

Hamilton, W. J., Jr. 1958. Life history and economic relations of the opossum, *Didelphis marsupialis virginianus*, in New York State. Cornell Univ. Agri. Exp. Sta. Memoir 354: 1-48.

Hartman, C. G. 1952. Possums. University of Texas Press, Austin, 174 pp.

Lay, D. W. 1942. Ecology of the opossum in eastern Texas. J. Mammal., 23 (2): 147-159.

LEWIS, J. B. 1929. Opossum in captivity. J. Mammal., 10 (2): 167-168.

LLEWELLYN, L. M. AND F. M. UHLER. 1952. The foods of fur animals of the Patuxent Research Refuge, Maryland. Am. Midl. Nat., 48 (1): 193-203.

MURIE, A. 1936. Following fox trails. Univ. Mich. Misc. Publ. Mus. Zool., 32:1-45.

PRAY, L. L. 1921. Opossum carries leaves with its tail. J. Mammal., 2 (2): 109-110.

RAVEN, H. C. 1929. A case of matricide in the opossum. J. Mammal., 10 (2):168.

REYNOLDS, H. C. 1945. Some aspects of the life history and ecology of the opossum in central Missouri. J. Mammal., 26 (4): 361-379.

ROBERTS, H. A. AND R. C. EARLY. 1952. Mammal survey of southeastern Pennsylvania. Pennsylvania Game Comm., Harrisburg. Final Report PR Project 43-4, 70 pp.

SANDIDGE, L. L. 1953. Food and dens of the opossum (*Didelphis virginianus*) in northeastern Kansas. Trans. Kans. Acad. Sci., 56 (1): 97-106.

SCOTT, T. G. AND W. D. KLIMSTRA. 1955. Red foxes and a declining prey population. Southern Ill. Univ. Monog. Ser. No. 1, 123 pp.

SETON, L. 1929. Lives of game animals. Doubleday, Doran and Co., Garden City, New York, vol. 4, 949 pp.

SMITH, L. 1941. An observation on the nest-building behavior of the opossum. J. Mammal., 22 (2): 201-202.

TAUBE, C. M. 1947. Food habits of Michigan opossums. J. Wildl. Mgt., 11 (1): 97-103.

WHEELER, R. J. 1939. Food habits of the opossum in Sumter County, Alabama. Unpublished M. S. Thesis, Library, Alabama Polytechnic Institute, Auburn, 56 pp.

WISEMAN, G. L. AND G. O. HENDRICKSON. 1950. Notes on the life history and ecology of the opossum in southeast Iowa. J. Mammal., 31 (3): 331-337.

WOOD, J. E. 1954. Food habits of furbearers of the upland post oak region of eastern Texas. J. Mammal., 35 (3): 406-415.

A LATE PLEISTOCENE MUSK-OX FROM EAST-CENTRAL ILLINOIS

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Recently, Mr. R. E. McClusky of the Ambraw Gravel Company, Lawrenceville, Illinois, presented the axis of a musk-ox, *Symbos cavifrons,* and fragments of a proboscidean limb bone to the Zoology Department of Southern Illinois University for inclusion in the Vertebrate Paleontology Collection.

These fossils were collected in the NW ¼ of Sec. 27, T 11 N, R 4 W, Lawrence County, Illinois, which would be on the west edge of George Field, an abandoned Army airfield located approximately four miles northeast of Lawrenceville. My inspection of the beds at this locality and the nature of the preservation of the bones suggest that the fossils came from a thin layer of brownish gravels, sands, or silts that overlay the thick, widespread beds of gravel and sand in the area. Dr. George E. Ekblaw, of the Illinois Geological Survey, informs me that the gravel in this area that composes the "second bottom" terrace at Lawrenceville was derived from glaciers terminating to the north in Indiana and were much later in time than the Shelbyville glacier.

In my opinion, this dating is in keeping with age determinations for other late Pleistocene fossils, including musk-ox, found in the Embarass drainage system almost 60 miles to the north (Galbreath, 1938).

The axis (No. P200, Vert. Paleont. Coll., Zool. Dept., S.I.U.) and the proboscidean fragments are heavy, massive, and completely mineralized fossils, well-charged with iron oxide that gives them a reddish orange color. The axis is damaged. Only the centrum and neural arch are preserved, but this is enough to enable one to recognize that the bone belonged to a musk-ox. Comparison of the specimen with the axis of a musk-ox reported by Hibbard and Hinds (1960) and identified by them as *Symbos cavifrons* leaves no doubt that the two bones belong to the same species. Fortunately, comparable bones or other parts from related musk-oxen are known (Kitts, 1953) that enables one to eliminate these species from possible consideration in determining the identity of this bone. The measurements of this Lawrenceville specimen are so close to those reported by Hibbard for his specimen that I see no reason to do more than report that the two specimens are similar in size.

This discovery of a musk-ox adds one more record to the list of known kinds of musk-oxen found in Illinois, and is the southernmost reliable record for the distribution of *Symbos cavifrons* in Illinois.

Cited References

Galbreath, E. C. 1938. Post-glacial fossil vertebrates from east-central Illinois. Geol. Ser. Field Mus. Nat. Hist., 6 (20): 303-313, 2 figs.

Hibbard, C. W. and F. J. Hinds. 1960. A radiocarbon date for a woodland musk-ox in Michigan. Papers Michigan Acad. Sci., Arts, and Letters, 45:103-111, 2 pls.

Kitts, D. B. 1953. A Pleistocene musk-ox from New York and the distribution of the musk-oxen. Amer. Mus. Nat. Hist. Novitates, No. 1607: 1-8, 2 figs.

CURRENT PROBLEMS BEARING ON THE METABOLIC STABILITY OF DEOXYRIBONUCLEIC ACID (DNA)

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In considering the orderliness and precision involved in the development of an organism, such as in the structural and functional differentiation of cells and tissues in multicellular forms, it becomes immediately apparent that there must be some system on which final order and form are based.

Furthermore, when we consider the transmission of heritable characters from parent to offspring, it is still further apparent that such a system must be capable of retaining a storehouse of information or a memory of specificities from generation to generation. In this capacity, deoxyribonucleic acid (DNA) is generally regarded as being the principal encoding mechanism for genetic information (Beadle, 1957; Brachet, 1957; Hotchkiss, 1955). During recent years, with the advent of reliable information as to the structure of the genetic material (Watson and Crick, 1953), it has been possible to give much greater meaning to the term "genetic information." Such information is visualized as being represented in the specific molecular organization of DNA.

Also, in reference to the template hypothesis (Brachet, 1955; 1957), it is possible to visualize mechanisms which can facilitate the translation of the specific information stored in the genetic material into the equally specific structural identity of macromolecules such as those synthesized during periods of growth and differentiation. In this connection, an intermediate substance acting in the effective transfer of genetic information from the gene to the specific end products of genic action is usually acknowledged. At least for the most part, this intermediate substance would seem to be ribonucleic acid (Brachet, 1957; Spiegelman, 1957).

With specific reference to DNA, this material is generally regarded as being a very stable substance. Actually, many investigators regard the relative constancy of the deoxyribonucleic acid in the "resting" cell nucleus as constituting a generally accepted hypothesis in modern biology. This assumption of constancy arises from a number of observations. First, it is accorded support by the fact that, except for periods of duplication, the DNA content per chromosome set is supposedly constant for any one species. This was first suggested by Boivin, Vendrely and Vendrely (1948), Mirsky and Ris (1949) and was later supported by numerous other investigations (Alfert and Swift, 1953; Swift, 1950). A second supporting evidence for this hypothesis lies in the general acceptance that, except for periods of gene replication, the low rate of turnover exhibited by deoxyribonucleic acid is indicative of high metabolic stability (Kihara, *et al.*,

1956; Smellie, 1955; Swick, *et al.*, 1956). Finally, such data, of course, tend to fit in with the general belief that DNA, as the genetic encoding material, must be maintained at a constant level and carefully conserved in interest of the genetic integrity of living organisms.

Although much support has been amassed in favor of the constancy hypothesis, the question may still be raised as to the absolute universality of this concept for all biological systems and for all physiological circumstances. Indeed, a considerable amount of data has been accumulated over recent years which necessitates a re-examination of this concept, at least in certain instances. Inconstancy has been reported in various developing and secretory tissues (Finamore and Volkin, 1958; Leuchtenberger and Schrader, 1952; Moore, 1957; Pelc, 1959; Rudkin and Corlette, 1957; Stich and Naylor, 1958, and others) and has allegedly been induced by cold treatment (LaCour, *et al.*, 1956; Stich and Naylor, 1958), hormonal changes (Common, *et al.*, 1951; Lowe, 1955; McShan, *et al.*, 1950), etc. It is quite apparent that in many cases where instability in the metabolic activity of DNA has been reported, such behavior has been directly related to concomitant variations in cellular proliferation and, therefore, to DNA synthesis involved in chromosomal replication. Such data, of course, do not stand in refutation of the constancy concept. However, at least some of the studies referred to here (*e.g.*, Finamore and Volkin, 1958; Moore, 1957; Pelc, 1959; Stich and Naylor, 1958) apparently are not resolvable on this basis and, indeed, seemingly stand in contradiction to the original context of the constancy hypothesis.

It is not the principal intent in this study to present a comprehensive review of the literature which stands in contradiction to the constancy hypothesis, as this has been done by various other investigators (Brachet, 1957; Govaert, 1957; Moore, 1957). Instead, chief concern will rest with an approach to the causal analysis of factors which may possibly underlie *certain* cases of DNA instability and the possible functional significance of such reported phenomena in nucleic acid biology.

In this connection, reference should be made to the extra DNA known to occur in the cytoplasm of many yolk-laden animal eggs (Fraenkel-Conrat, *et al.*, 1952; Hoff-Jorgensen and Zeuthen, 1952; Solomon, 1957). It is thought that this material may represent a general storage reservoir which functions to support DNA synthesis during early embryonic development (Hotchkiss, 1955; Solomon, 1957). In reference to this "cytoplasmic DNA", Solomon (1957, p. 589) states, "The nucleic acids (or similar highly polymerized compounds) may be a convenient means of storing nucleic acid precursors, which could be obtained by degradation when required by the embryo." Commenting on the same point, Hotchkiss (1955) suggests that this substance may very likely exist as a genetically nonspecific precursory form of DNA.

Of interest here is the recent work of Foster and Stern (1958, 1959)

which indicates that extra sources of DNA are exploited to support DNA replication in developing pollen of lily anthers. They have shown that the breakdown products from DNA of certain neighboring tissues serve as a source of deoxynucleosides for DNA synthesis in the microsporocytes and microspores. These findings stress the possible worth of "extra sources" of DNA in providing prescursory substances for nucleic acid synthesis.

Attention should also be directed to studies on the "puffs" of the salivary gland chromosomes of certain species (Beermann, 1959; Rudkin and Corlette, 1957; Stich and Naylor, 1958, and others). Puff formation seems to be quite specific for particular chromosomal segments, varying characteristically with different cell types and developmental stages. As noted by Beermann (1959), such behavior perhaps reflects specific genic activity. Of special interest here is the localized build-up of DNA known to occur during puff formation in certain species. As shown by Stich and Naylor (1958), certain puffs in *Glyptotendipes* (Chironomidae) show as much as an 8-fold increase in DNA content at certain developmental periods. Also, it is apparent that the DNA content of a particular puff varies independently from other segments of the same chromosome. It seems possible that in some instances *specific fractions* of DNA (or high molecular weight polydeoxyribonucleotides) may form at certain chromosomal sites and, upon being released, perhaps serve in transmitting genetic information, similar to messenger RNA. As DNA does not commonly occur in cellular cytoplasm, such polydeoxyribonucleotides would perhaps function in the intranuclear synthesis of certain specific macromolecules, presumably by playing an intermediate role in information transfer from specific genic loci to specific end-products of genic action.

It is acknowledged that the suggestions noted above are largely tentative, and that the pertinence of such ideas to nucleic acid biology cannot be fully determined at present.

Reference

Alfert, M. and H. Swift. 1953. Nuclear DNA constancy: A critical evaluation of some exceptions reported by Lison and Pasteels. Exptl. Cell. Res., 5: 455-460.

Beadle, G. W. 1957. The role of the nucleus in heredity. *In* The Chemical Basis of Heredity, edited by W. D. McElroy and B. Glass. Johns Hopkins Press, Baltimore, pp. 3-22.

Beermann, W. 1959. Chromosomal differentiation in insects. *In* Developmental Cytology, edited by D. Rudnick. Ronald Press, New York, pp. 83-103.

Birge, W. J., G. W. Salisbury, L. de la Torre, and J. R. Lodge. 1960. Diminution of the deoxyribonucleic acid content of bovine spermatozoa during *in vitro* storage. Anat. Rec., 137: 340.

Birge, W. J., G. Anklesaria and F. D. Tibbitts. 1961. Differential response of DNA of fresh and stored bovine spermatozoa to Feulgen (HCl) hydrolysis. Trans. Ill. Acad. Sci., 54: 107-111.

Boivin, A., R. Vendrely, and C. Vendrely. 1948. L'acide desoxyribonucleique du noyau cellulaire, depositaire des characteres hereditaires; arguments d'ordre analytique. Compt. Rend. Acad. Sci., 226: 1061-1063.

Brachet, J. 1955. The biological role of the pentose nucleic acids. *In* The Nucleic Acids. Vol. II, edited by E. Chargaff and J. N. Davidson. Academic Press, New York, pp. 475-519.

BRACHET, J. 1957. Biochemical Cytology. Academic Press, Inc., New York, 1st Ed.

COMMON, R. H., D. G. CHAPMAN, and W. A. MAW. 1951. The effect of gonadal hormones on the nucleic acid content of liver and serum in the immature pullet and the difference between the nucleic acid content of livers of sexually mature pullets and cockerels. Can. J. Zool., 29: 265-275.

FINAMORE, F. J. and E. VOLKIN. 1958. Nucleotide and nucleic acid metabolism in developing amphibian embryos. II. Composition and metabolic activity of ovarian egg nucleic acids. Exptl. Cell. Res., 15: 405-411.

FOSTER, T. S. and H. STERN. 1958. Soluble deoxyribosidic compounds in relation to duplication of deoxyribonucleic acid. Science, 128: 653-654.

FRAENKEL-CONRAT, H., N. S. SNELL and E. D. DUCAY. 1952. Avidin I. Isolation and characterization of the protein and nucleic acid. Arch. Biochem. Biophys., 39: 80-96.

GOVAERT, J. 1957. Etude quantitative de la teneur en acide desoxyribonucleique des noyaux des cellules somatiques et germinatives chez *Fasciola hepatica*. Arch. Biol. (Liege), 68: 165-200.

HOFF-JORGENSEN, E. and E. ZEUTHEN. 1952. Evidence of cytoplasmic deoxyribosides in the frog's egg. Nature, 169: 245-246.

HOTCHKISS, R. D. 1955. The biological role of the deoxypentose nucleic acids. *In* The Nucleic Acids, Vol. II, edited by E. Chargaff and J. N. Davidson. Academic Press, New York, pp. 435-473.

KIHARA, H. K., N. AMANO, and A. SIBATANI. 1956. Stability of deoxypentose acid in growing and non-growing livers of young rats. Biochem. et Biophys. Acta, 21: 489-499.

LACOUR, L. F., E. M. DEELY, and J. CHEYEN. 1956. Variations in the amount of Feulgen stain in nuclei of plants grown at different temperatures. Nature, 177: 272.

LEUCHTENBERGER, C., and F. SCHRADER. 1952. Variation in the amounts of desoxyribose nucleic acid (DNA) in cells of the same tissue and its correlation with secretory function. Proc. Natl. Acad. Sci., 38: 99-105.

LOWE, C. V. 1955. Effects of cortisone on nucleic acid composition of rat liver. J. Natl. Cancer Inst., 15: 1619-1622.

MCSHAN, W. H., J. S. DAVIS, S. W. SOUKUP, and R. K. MEYER. 1950. The nucleic acid content and succinic dehydrogenase activity of stimulated pigeon crop gland tissue. Endocrinology, 47: 274-280.

MIRSKY, A. W. and V. ALLFREY. 1957. The role of the cell nucleus in development. *In* The Chemical Basis of Development, edited by W. D. McElroy and B. Glass. Johns Hopkins Press, Baltimore, pp. 94-102.

MIRSKY, A. and H. RIS. 1949. Variable and constant components of chromosomes. Nature, 163: 666-667.

MOORE, B. C. 1957. DNA in diploid and androgenetic amphibian hybrids. J. Morph., 101: 227-274.

PELC, S. R. 1959. Metabolic activity of DNA as shown by autoradiographs. Lab. Invest., 8: 225-236.

RUDKINS, G. T. and S. L. CORLETTE. 1957. Disproportionate synthesis of DNA in a polytene chromosome region. Proc. Natl. Acad. Sci., 43: 964-968.

SALISBURY, G. W., W. J. BIRGE, L. DE LA TORRE, and J. R. LODGE. 1960. Decrease in nuclear Feulgen-positive material (DNA) upon aging in *in vitro* storage of bovine spermatozoa. J. Biophysical and Biochemical Cytology, 10: 353-359.

SMELLIE, R. M. S. 1955. The metabolism of the nucleic acids. *In* The Nucleic Acids, Vol. II, edited by E. Chargaff and J. N. Davidson. Academic Press, New York, pp. 393-434.

SOLOMON, J. B. 1957. Nucleic acid content of early chick embryos and the hen's egg. Biochimica et Biophysica Acta, 24: 584-591.

SPIEGELMAN, S. 1957. Nucleic acids and the synthesis of proteins. *In* The Chemical Basis of Heredity, edited by W. D. McElroy and B. Glass. Johns Hopkins Press, Baltimore, pp. 232-267.

STERN, H. 1959. Mitosis and metabolic organization. The Botanical Review, 25: 351-384.

STICH, H. F. and J. M. NAYLOR. 1958. Variation of desoxyribonucleic acid content of specific chromosome regions. Exptl. Cell. Res., 14: 442-445.

SWICK, R. W., A. L. KOCH, and D. R. HANDA. 1956. The measurement of nucleic acid turnover in rat liver. Arch. Biochem. and Biophys., 63: 226-242.

SWIFT, H. 1950. The desoxyribose nucleic acid content of animal nuclei. Physiol. Zool., 23: 169-198.

WATSON, J. D. and F. H. C. CRICK. 1953. Molecular structure of nucleic acids. Nature, 171: 737-738.

CORRELATION BETWEEN PHENOLOGY AND CALORIC CONTENT IN FOREST HERBS

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Several phenological studies have been made in which factors such as breaking of dormancy, flowering, fruiting and seed dispersal of forest herbs have been recorded (Wolfe, Wareham and Scofield, 1949; Leopold and Jones, 1947; Deam, 1920-1952). Smith (1915) and Hopkins and Murray (1933) found that the time of occurrence of major events in plant development remained relatively constant from year to year. Lindsey and Newman (1956), on the other hand, found considerable variation for at least the first flowering dates of many herbaceous species in Indiana. They considered temperature to be the most important factor controlling time of flowering.

Closing of the canopy and leaf abscission cause considerable changes in the environment of the understory plants. Expansion of tree leaves causes a great reduction in sunlight, temperature fluctuation, precipitation, transpiration rate and wind velocity at the forest floor. These microenvironmental changes presumably cause readjustments in the physiological activity and phenological sequence of the plants in the lower synusia. Meyer and Anderson (1952) reported that exceptionally high respiration and assimilation rates occur in floral meristems and that various foods, inorganic compounds and water are translocated to developing flowers. They stated, however, that little is actually known about metabolic activities during flower and fruit production.

Golley (1958) compiled a list of caloric determinations for various plants from contributions by several investigators. However, none of these determinations were done on a phenological basis. Golley (1960) made caloric determinations on some of the species comprising an old field community in southern Michigan but found little seasonal variation. While considerable research is being done on the consumption and expenditure of energy in certain animal species during various phases of their life cycles, little or no research is being done on the energy dynamics of individual species of plants. The author is unaware of any studies relating changes in caloric content with plant development. The objective of this study was to determine whether any changes in energy content occur during the growing season, and if so, whether they are correlated with changes in plant phenology.

Methods

Native spring and early summer flowering herbs were collected from a 10 x 10 m plot in Trelease Woods (Section 1 T19N R9E) Champaign County, Illinois. The species collected included: *Claytonia virginica* (spring beauty), *Dicentra canadensis* (squirrel corn), *Trillium recurvatum* (purple trillium), *Osmorhiza*

longistylis (sweet cicely) and *Hydrophyllum canadense* (waterleaf). Nomenclature is that of Jones (1950). Voucher specimens are on deposit in the University herbarium.

Only one plot was used in order to confine the collecting to a relatively uniform habitat. With reduced variation in habitat, variations in caloric content could be more easily correlated with phenological variation. Collections were made at approximately one week intervals from March 31 to June 1, 1960, and at approximately two week intervals from the latter date until August 3. Both roots and shoots were collected. The number of plants collected depended upon the species and upon the phenological condition. Approximately 50 g (fresh weight) samples were collected for each species. After extraneous material was removed and roots were washed to remove soil, the samples were oven dried for about 48 hours at 80° C and ground twice in a Wiley mill (20 mesh/in).

Caloric content determinations were made using a Parr adiabatic oxygen bomb calorimeter. Two determinations were made on each sample (except where widely divergent results were obtained, in which case a third determination was made). Values were not corrected to an ash-free weight basis. Average caloric values for carbohydrates (4100 cal/g), proteins (5700 cal/g) and fats (9400 cal/g) obtained from Fruton and Simmons (1953) were used as a standard for the interpretation of experimental data.

A slightly modified form of Nessler's Procedure (Umbreit, Burris and Stauffer, 1957) was used for analysis of total nitrogen content. Duplicate 4mg samples were digested in Nessler tubes by adding 1 ml of 20% H_2SO_4 (no copper selenite added) and heating on an electric plate for about an hour. After cooling for at least a minute, 2 drops of 30% H_2O_2 were added, and heating was resumed for 15 minutes. Cooling, adding of H_2O_2 and heating were repeated a second time in order to completely clear the samples. When the tubes had cooled to room temperature, 20 ml of deionized water were added and the samples stirred vigorously. Stirring was repeated after addition of 4 ml of 4N KOH and again after addition (by blowing) of 2 ml Nessler's reagent. This solution was diluted to 35 ml with deionized water and allowed to stand for 15 minutes. Optical density was measured with a spectrophotometer at 490 mμ. These readings were then converted to mg protein/g dry weight (Nx6.25).

Though no quantitative environmental data were obtained, generalized observations of climatic conditions were recorded along with observations of phenological condition of the species collected. The latter included observations of the time and amount of vegetative growth, flower bud initiation, flowering, fruit development and vegetative drying. A record was also kept of the initiation, the gradual development and the complete closing of the tree canopy.

Phenological Observations

The first observations of the study

area were made on March 29. Although a heavy snow had just melted three days previously, all of the species mentioned above had broken dormancy. In fact, *Claytonia, Hydrophyllum* and *Osmorhiza* had already penetrated the leaf litter. By March 31, some *Dicentra* were beginning to appear above the litter. Abundant etiolated stems of *Claytonia* were found below the humus, and flower buds were already present. *Trillium* ranged in height from 4 to 6 cm, *Osmorhiza* from 2 to 3 cm.

On April 3 about 10% of *Claytonia* flowers were open with the remaining buds showing pink color. Only a small amount of vegetative growth occurred in all species between March 29 and April 8 due to abnormally low temperatures (Illinois State Water Survey data, March - April, 1960). By this date, however, large buds were present on *Trillium*. *Claytonia* was in full bloom on April 14 and continued to be so for about 10 days. Although flower buds were visible on *Dicentra* on the 14th, full bloom was not attained until the 20th. Flowering had just begun in *Trillium*, while considerable leaf expansion had occurred in *Osmorhiza* and *Hydrophyllum*. Leaf buds were just beginning to expand in the canopy, but leaf development was almost completed on buckeye seedlings and saplings.

By April 27 most *Dicentra* and *Claytonia* were through blooming, while *Trillium* was in full flower. *Osmorhiza* and *Hydrophyllum* continued vegetative growth. *Hydrophyllum*, rather than *Claytonia* and *Dicentra*, now formed the predominant herbaceous cover.

Although *Dicentra* produced very few fruits, those which were formed were mature on May 4. Leaves of this species were turning yellow on this date, and many new corms were observed. The fruits of *Claytonia* were nearly all mature, and the petals of many *Trillium* flowers had dropped. Flower buds were present on about 50% of *Osmorhiza*. The leaves of *Hydrophyllum* had attained a height of about 45 cm. In areas where *Hydrophyllum* was sparse, *Laportea canadensis* had become very predominant in the herbaceous layer.

During the week from May 4 to May 11, little change took place due to cold, wet weather. However, *Claytonia* seeds were dispersed; *Dicentra* leaves were dying; most *Trillium* were through blooming. The tree canopy began to close during this week. By May 18 the canopy was almost completely developed, *Dicentra* and *Claytonia* had disappeared from the herbaceous layer and a few *Hydrophyllum* were in bloom, although flower buds were not yet visible on many individuals.

On May 25 the canopy was fully developed. *Laportea* was 0.7 to 1 m in height, and yellowing was observed in *Trillium*. By June 1 *Trillium* was drying. The majority of *Osmorhiza* were in fruit by the latter date, while approximately 90% of *Hydrophyllum* were in bud.

The author was not in Urbana after June 1. Therefore, no further field observations of phenological condition were recorded. However, while preparing samples for grinding, it was noted that fruits of *Osmorhiza* were green on June 23 and had matured by July 7.

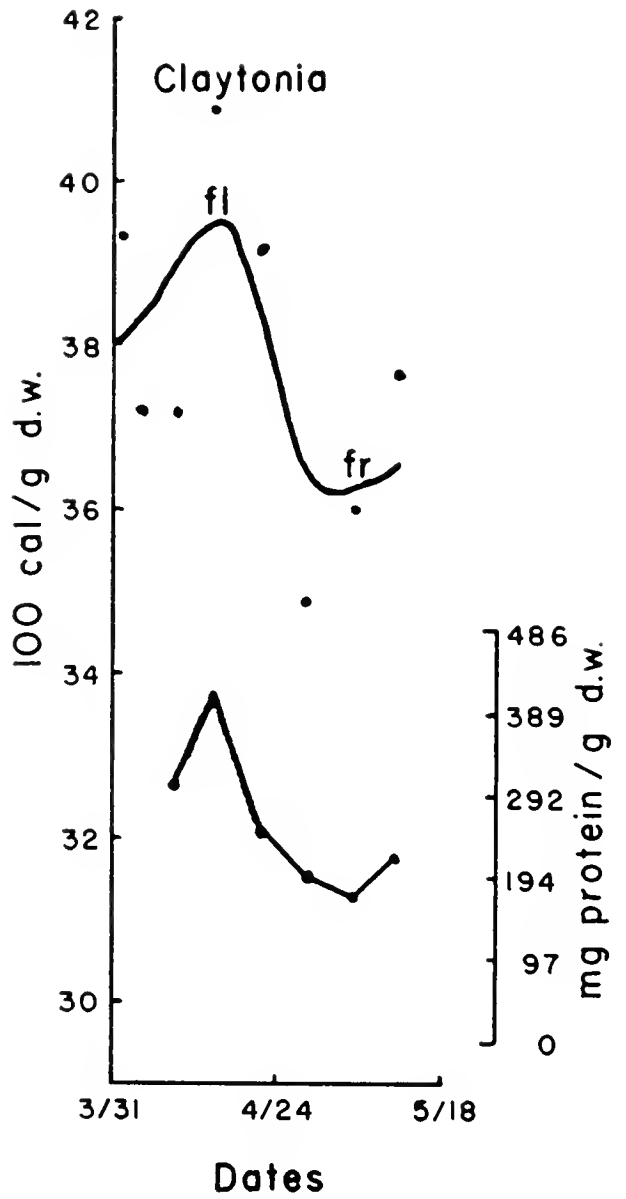

FIG. 1.—Caloric and protein determinations for *Claytonia virginica*, (fl-flowering, fr-fruiting).

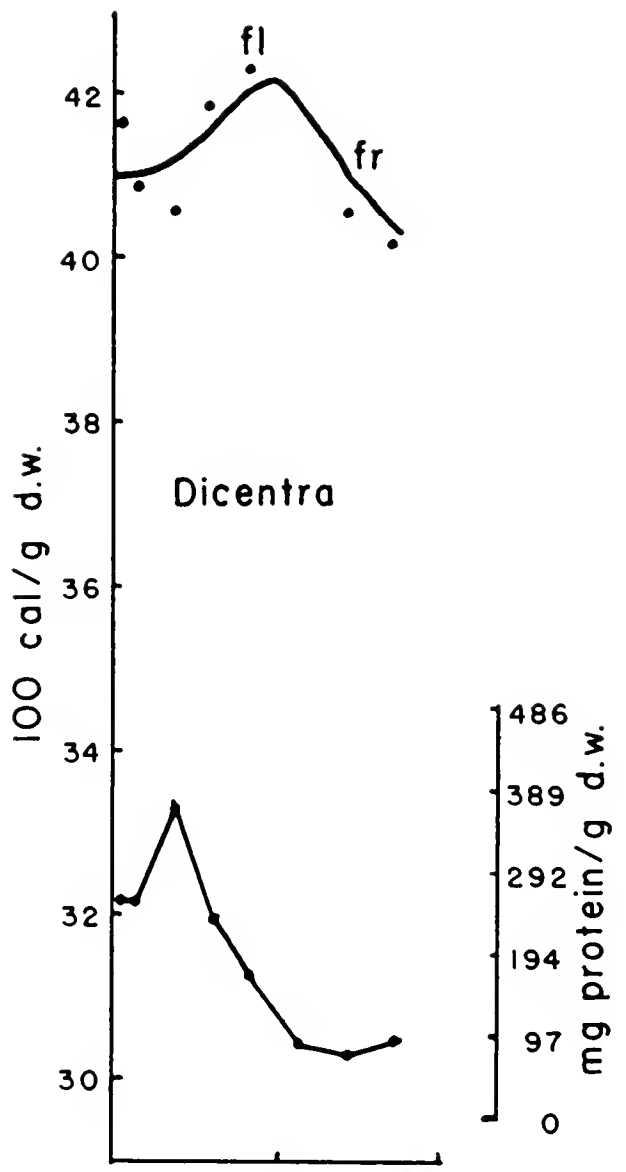

FIG. 2.—Caloric and protein determinations for *Dicentra canadensis*.

RESULTS AND DISCUSSION

Caloric content was found to vary with plant development. *Claytonia virginica* (Fig. 1) and *Dicentra canadensis* (Fig. 2) showed a peak in caloric content at maximum flowering, while the peak for *Trillium recurvatum* (Fig. 3) occurred at maximum flower bud development (general curves were drawn from sight inspection). Caloric values for *Claytonia* dropped from 4100 cal/g at flowering to 3500 cal/g two weeks after flowering. By the time of vegetative die back, caloric content rose to about 3750 cal/g. *Dicentra* and *Trillium* showed a continuous drop in caloric content following peak values. *Dicentra* dropped from 4250 cal/g at flowering to about 4000 cal/g at vegetative die back, while *Trillium* dropped from 4200 cal/g at maximum floral bud development to about 3950 cal/g at dormancy. *Osmorhiza longistylis* (Fig. 4) and *Hydrophyllum canadense* (Fig. 5), on the other hand, showed a continuous increase in calories per gram over the entire growing season. Caloric values for *Osmorhiza*

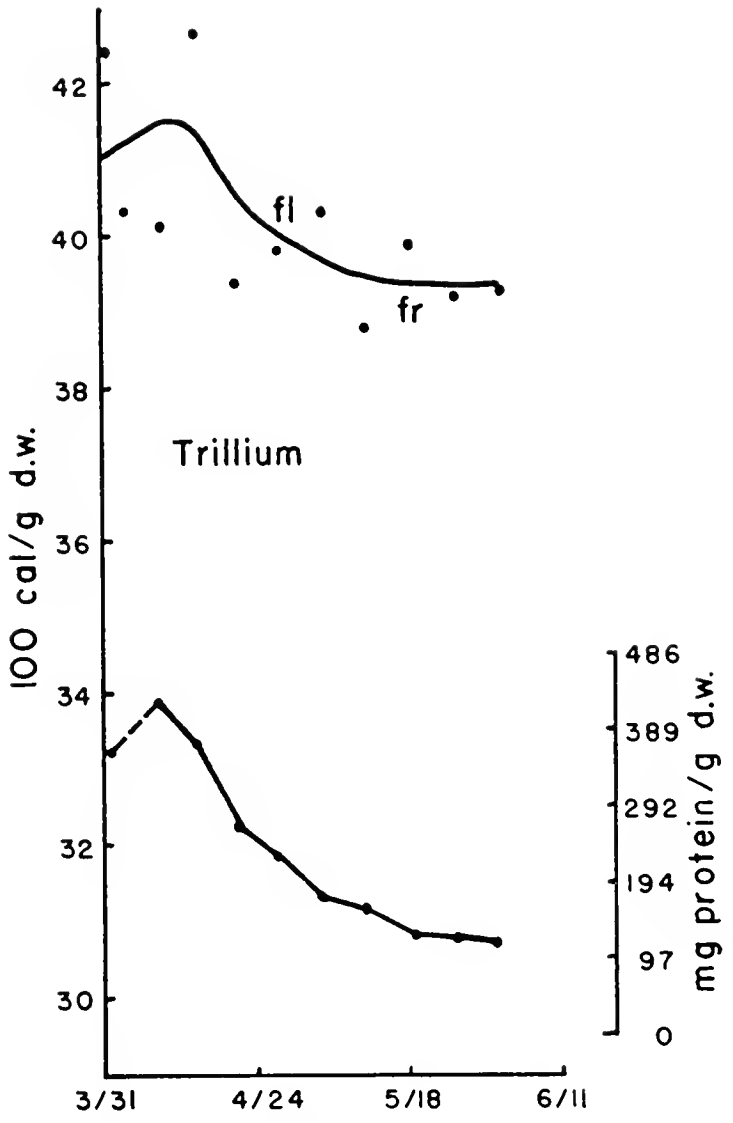

FIG. 3.—Caloric and protein determinations for *Trillium recurvatum*.

increased from about 3500 cal/g at the beginning of the season to approximately 4100 cal/g at the end. Values for *Hydrophyllum* rose from 3250 cal/g to 3800 cal/g followed by a slight drop (to 3700 cal/g) at the end of the summer.

Corrections of caloric values to an ash-free weight basis were made on limited amounts of material at a later date. A rise in caloric values occurred in every case, but the general seasonal pattern was maintained. The extent to which the values increased varied with the species.

The variation in time of maximum caloric content between the species could possibly be explained by inherent differences. Differences in the manner and time of floral development may be associated with differences in time of peak caloric content in *Claytonia, Dicentra* and *Trillium*. *Claytonia* produces flowers and leaves on the same stem. Flower buds are already present when the stem appears above the litter. The same is true for *Trillium* except that only one large flower bud is produced per plant. *Dicentra* differs in that flowers are produced on a scape when vegetative growth is nearly complete. *Claytonia, Dicentra* and *Trillium* grow, reproduce and die back within two months, while vegetative growth occurs for a much longer period of time in *Osmorhiza* and *Hydrophyllum*. The ratio of organic to inorganic matter probably increases due to continuous vegetative growth. This could account for the continuous rise in caloric content in the latter two species during the growing season.

Total protein was also found to vary with phenological development in *Claytonia, Dicentra* and *Trillium*. Maximum protein content in *Claytonia* (Fig. 1) occurred at maximum flowering. Total protein dropped from about 412 mg/g dry weight at flowering to 170 mg/g a week before complete die back. A slight rise in protein occurred during the last week resulting in a curve similar to that for caloric content. Apparently the rise in caloric values is related to a relative increase in protein content. The latter may be due, in *Claytonia*, to continued production of vegetative and floral structures until flowering occurs.

The peak in caloric content for

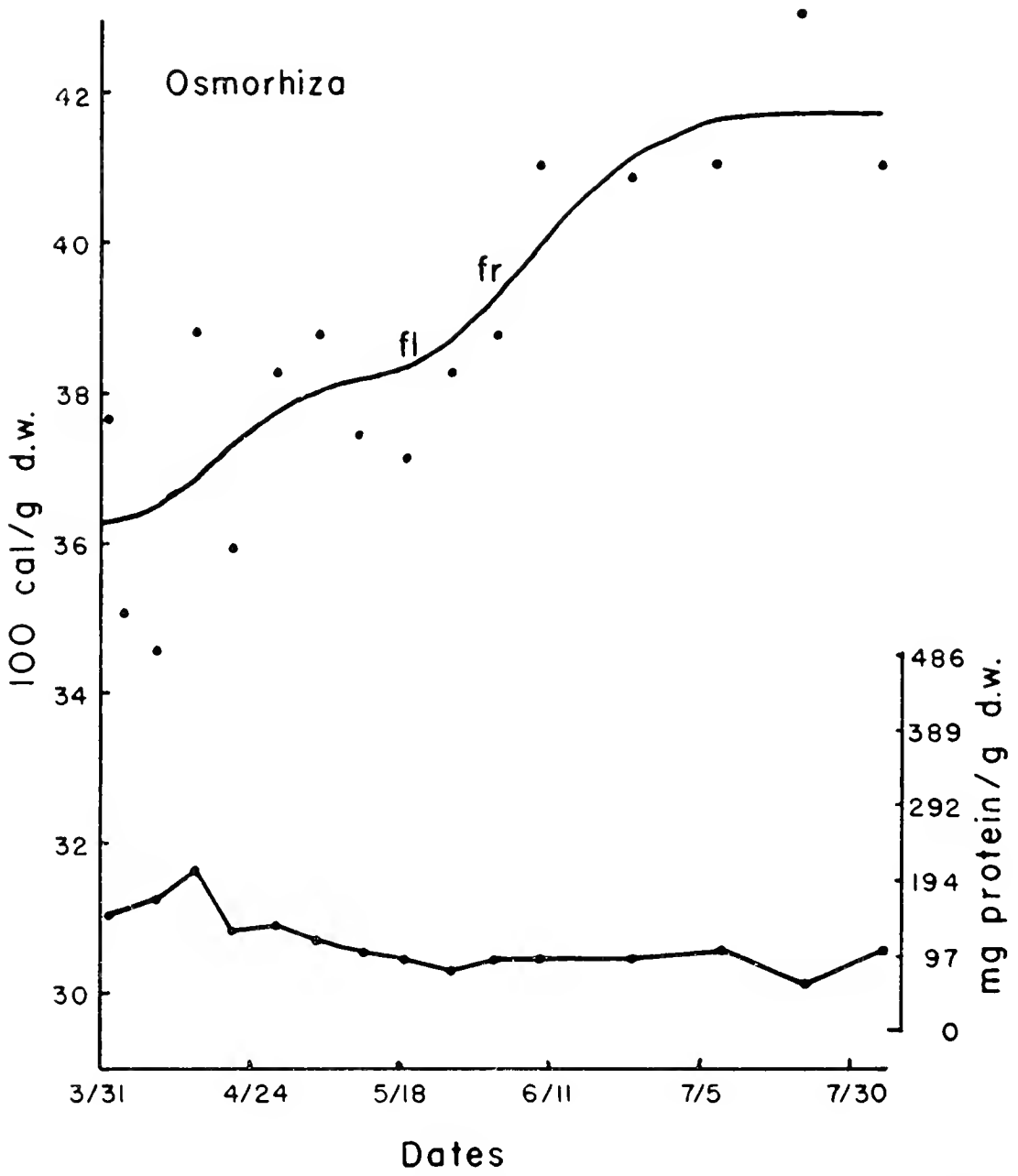

FIG. 4. Caloric and protein determinations for *Osmorhiza longistylis*.

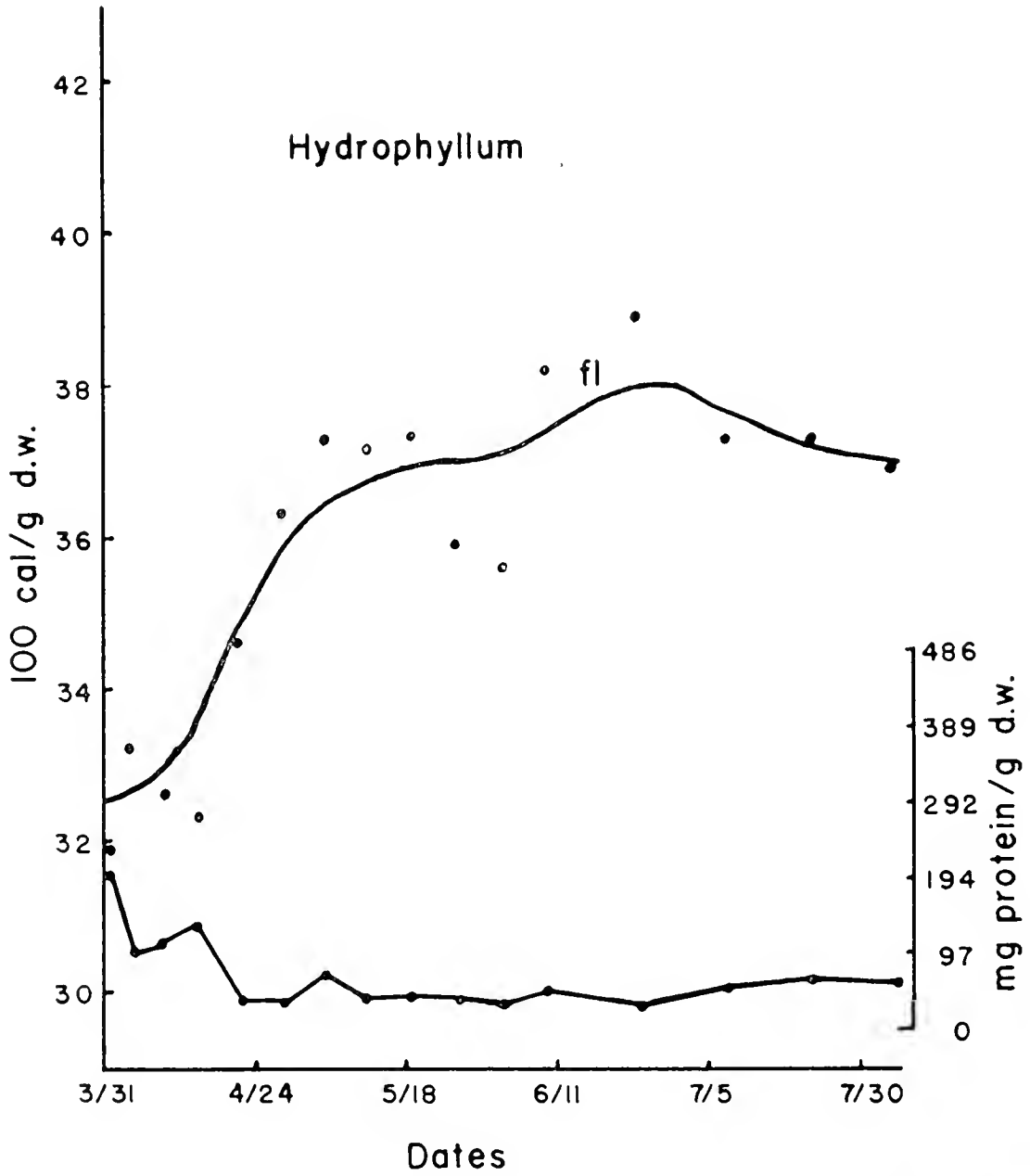

FIG. 5. Caloric and protein determinations for *Hydrophyllum canadense*.

Trillium lagged slightly behind the peak in protein content. The latter occurred during maximum vegetative and floral bud development. Total protein dropped continuously from the peak of about 435 mg/g to about 122 mg/g at vegetative die back. It appeared that most tissue production and differentiation was completed somewhat before flowering and that further growth was due to expansion of existing cells. The relative increase in amount of total protein during production and differentiation of vegetative and floral structures could account for most of the increase in caloric content. However, the higher caloric values in *Trillium* probably indicate formation of some lipids.

In *Dicentra* the peak in protein content occurred, as in *Trillium,* during maximum vegetative and floral bud development. Protein content dropped continuously from a maximum of about 365 mg/g at this time to about 90 mg/g at vegetative die back. A lag, greater than that in *Trillium,* occurred between peak protein content and peak caloric content. Leaf and flower bud production and differentiation were completed well before flowering. Petiole and scape length increased to the time of flowering, but leaves simply unfolded and flower buds expanded for a period of at least a week prior to flowering. Increase in total protein appeared, therefore, to be related to the period of maximum tissue formation and differentiation. Since the lag between maximum protein and maximum caloric content was considerable, relative increase in the amount of protein probably did not account for the peak in caloric content in *Dicentra.* Lipid formation may account for the peak, a possibility which is supported by the relatively high caloric values.

The initial values for caloric and protein content for *Claytonia, Dicentra* and *Trillium* were well above the values at vegetative die back. Thus, some conversion of carbohydrates to proteins or lipids must take place in the bulbs, corms or root systems of these species during the dormant period.

Protein content per gram in *Osmorhiza* and *Hydrophyllum* did not vary with plant phenology. Both species had values close to 97 mg/g throughout the growing season. Therefore, rise in caloric content can not be attributed to a rise in protein content. If an increased organic to inorganic matter ratio occurs, the increase must be in the form of carbohydrates or fats. Since the total rise in caloric content was great, increased lipid formation is probably the causal factor. Caloric values for the last collection date were well above initial values for both of these genera. However, drying had not occurred in either species when collection ceased. A drop in caloric values would probably occur with the shedding of fruits and the drying of leaves.

An analysis of variance was run on this factorial experiment in a completely randomized design. The results show that caloric values for different species, for different dates and for the effect of species upon dates were significant at the 1% level.

Summary

Three species of spring flowering herbs (*Claytonia virginica, Dicentra canadensis* and *Trillium recurvatum*) and two species of summer flowering herbs (*Osmorhiza longistylis* and *Hydrophyllum canadense*) were studied to determine whether changes in plant development are correlated with changes in caloric and protein values. The plants were collected from a 10 x 10 m plot in Trelease Woods (Section 1 T19N R9E) Champaign County, Illinois, at 1 to 2 week intervals from March 31 through August 3, 1960. Time of maximum vegetative growth, flower bud development, flowering, fruiting and vegetative die back were recorded. Notes were also taken on canopy development and on general climatic conditions. Caloric determinations were made on oven dried, ground samples using a Parr adiabatic oxygen bomb calorimeter. A modified form of Nessler's Procedure was used to determine total nitrogen content. The results were then converted to total protein content.

A correlation was found between time of maximum leaf and flower development and peak caloric content in *Claytonia, Dicentra* and *Trillium.* These species grow, flower, fruit and die back in a two month period. Caloric values for *Osmorhiza* and *Hydrophyllum* rose almost continuously throughout the growing season. These species are physiologically active during most of the summer and, thus, there appears to be no correlation between peak caloric values and time of maximum growth.

The curves for caloric and protein content were quite similar in *Claytonia* and *Trillium;* both reached a peak at flowering. The peak in protein content occurred well ahead of the peak in caloric content in *Dicentra,* while in *Osmorhiza* and *Hydrophyllum,* protein remained constant (and low) during the entire growing season. Since no significant increase in protein was found in the latter two species, increased lipid content may account for the rise in caloric values. Some conversion of carbohydrates to proteins or fats must occur during dormancy in the corms, bulbs or root systems of *Claytonia, Dicentra* and *Trillium* in order to bring caloric values back to their initial value by the following spring.

Acknowledgment

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Literature Cited

Deam, C. C. 1920-1952. Unpublished phenological records as cited in Lindsey and Newman.

Fruton, J. S. and Sofia Simmons. 1953. General biochemistry. New York, John Wiley and Sons, Inc., 940 pp.

Golley, F. B. 1958. Table of caloric equivalents. Unpub. data.

———. 1960. Energy dynamics of a food chain of an old-field community. Ecol. Monog., 30:187-206.

Hopkins, A. D. and M. Murray. 1933. Natural guides to the beginning, length, and progress of the seasons. Acta Phaenol., 2:33-43.

Illinois State Water Survey Division. 1960. Champaign-Urbana weather summary. March - April - May.

JONES, G. N. 1950. Flora of Illinois. Notre Dame, Indiana, Univ. of Notre Dame Press, 368 pp.

LEOPOLD, A. and SARA E. JONES. 1947. A phenological record for Sauk and Dane Counties, Wisconsin, 1935-1945. Ecol. Monog., 17:81-122.

LINDSEY, A. A. and J. E. NEWMAN. 1956. Use of official weather data in spring time—temperature analysis of an Indiana phenological record. Ecology, 37:812-823.

MEYER, B. S. and D. B. ANDERSON. 1952. Plant physiology (2nd Ed.) Princeton, New Jersey, D. Van Nostrand Co., 784 pp.

SMITH, J. W. 1915. Phenological dates and meteorological data recorded by Thomas Mikesell between 1873-1912 at Wauseon, Ohio. Month. Weath. Rev. Sup. No. 2., pp. 23-93. (as cited in Wolfe *et al.* 1949).

UMBREIT, W. W., R. H. BURRIS and J. F. STAUFFER. 1957. Manometric techniques. Minneapolis, Minnesota, Burgess Pub. Co., 338 pp.

WOLFE, J. N., R. T. WAREHAM and H. T. SCOFIELD. 1949. Microclimates and macroclimates of Neotoma, a small valley in central Ohio. Ohio Biol. Surv., Bull. 41, 267 pp.

A RE-EXAMINATION OF RETAIL TRADE IN THE "DISPERSED CITY" OF SOUTHERN ILLINOIS

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Whereas southern Illinois lacks an urban center of more than 20,000 persons, several of its larger cities have been said to function as a single, albeit dispersed city. Reference to this dispersed city was first made by Oliver Beimfohr (1953:100), within the context of a study focusing on the industrial potential of southern Illinois. A more detailed study by Ian Burton (1959:145), on the basis of traffic flow and population density, set the limits of the dispersed city in a four county area composed of Williamson, Perry, Franklin, and Jackson counties. This area includes an urban core of thirteen major cities ranging in population size from more than 14,000 to slightly over 1,000 inhabitants. (Fig. 1)

Earlier works have failed to formulate a concise definition of the term "dispersed city," but we may gather, especially from the study of Burton (1959:145), that it refers to a group of politically discrete cities, separated by rather large tracts of rural land, which functionally inter-act to the extent that they may be referred to as a single unit lacking a downtown shopping district. The purpose of this paper is

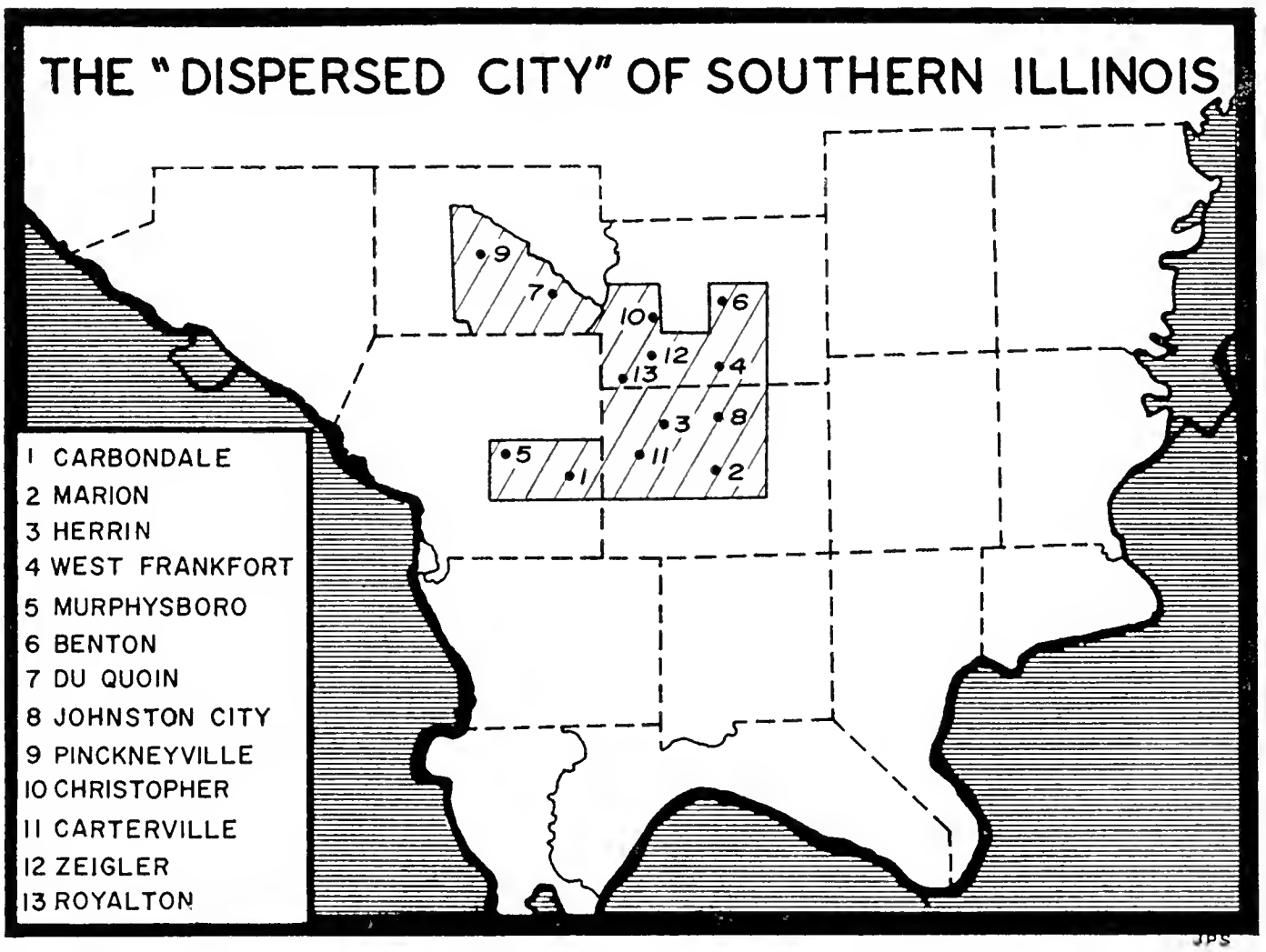

FIGURE 1.—A Re-Examination of Retail Trade in the "Dispersed City."

to analyze the retail functions of the major centers of the "dispersed city" in an effort to ascertain if inter-action among them is sufficient to warrant calling them a single unit.

Methods

Inter-action among the various centers is the key to the entire concept of the dispersed city. The best insights into this phenomenon probably could be gained from detailed field work in each of the cities involved. Limitations in time and resources placed such an investigation beyond the scope of this study.

Burton (1959:148-9) approached inter-action by analyzing the relationship between population and several types of retail sales. He assumed that a relatively high degree of association normally exists between the variables examined and proceeded to search for anamolies in the existing pattern. For example, unless inter-action is remarkably uniform, certain cities would have disproportionately large volumes of retail trade because they are able to attract business from other sections of the dispersed city; specialization of certain retail commodities would be especially likely to develop under such circumstances.

This study makes use of Burton's method, but goes beyond his and other previous works by comparing the retail patterns of the "dispersed city" to similar groups of urban units. This approach is based on the assumption that if inter-action is unique within the "dispersed city," it is probable that the associations of population with the various categories of retail trade in the "dispersed city" differ markedly from associations found in groups of cities of similar sizes.

To form a basis for comparison four sample groups of cities in Illinois were selected. Three of these (A, B, and C) consisted of thirteen cities each, and were structured to approximate as closely as possible the rank order of population of the units found in the dispersed city. Thus, the largest city in each group approximated the population of Carbondale, the biggest unit in the "dispersed city;" the second largest city in each group approached the population of Marion, the second largest city in the "dispersed unit." Sample group D consisted of thirty-five cities and was chosen at random from all Illinois cities having populations of more than 1,000. (Table I) Although the small sizes of the samples necessitate caution when using statistical analysis, a quantitative indication of the variability between population and several categories of retail trade was obtained by correlation analysis. (Table II)

Discussion

Burton (1959:147-8) pointed to a weak association between population and total retail sales of the larger units of the dispersed city and cited this as evidence of inter-action. His conclusion was based on a comparison of 1950 population figures and 1957 sales tax data; on the other hand when this author compared 1960 population statistics to 1960 sales tax data, a high positive correlation was apparent. (Fig. 2) In fact, the statistical relationship between these variables was higher

TABLE I. Population of Places in the "Dispersed City" and Sample Groups.

Dispersed City		*Group A*		*Group B*		*Group C*	
Carbondale	14,670	Centralia	13,904	Canton	13,588	Mt. Vernon	15,566
Marion	11,274	Macomb	12,135	Belvidere	11,223	LaSalle	11,897
Herrin	9,474	Cairo	9,348	Rock Falls	10,261	Paris	9,823
West Frankfort	9,027	Taylorville	8,801	Olney	8,780	Harrisburg	9,171
Murphysboro	8,673	Mt. Carmel	8,594	Effingham	8,172	Pontiac	8,435
Benton	7,223	Rochelle	7,008	Sycamore	6,961	Litchfield	7,330
DuQuoin	6,558	Fairfield	6,362	Hoopeston	6,606	Pana	6,432
Johnston City	3,891	Sandwich	3,842	Tuscola	3,875	Sullivan	3,946
Pickneyville	3,085	Dwight	3,086	Aledo	3,080	Galva	3,060
Christopher	2,854	Rushville	2,819	Farmington	2,831	Coal City	2,852
Carterville	2,643	Lewiston	2,603	Green Rock	2,677	Nashville	2,606
Zeigler	2,133	Arthur	2,120	Lacon	2,125	Leroy	2,088
Royalton	1,225	Chrisman	1,221	Coulterville	1,222	Erie	1,215

Group D			
Decatur	78,004	Zeigler	2,133
Berwyn	54,244	Elmwood	1,882
Danville	41,856	Sesser	1,764
Park Ridge	32,659	Jerome	1,666
Oak Park	27,471	Winfield	1,575
Franklin Park	18,322	Atlanta	1,568
Canton	13,588	Bunker Hill	1,524
Homewood	13,371	Oswego	1,510
Edwardsville	9,996	Park City	1,408
Paris	9,823	St. Anne	1,378
Batavia	7,946	LaHarpe	1,322
Princeton	6,250	Dallas City	1,276
Phoenix	4,203	Fisher	1,155
Matteson	3,225	Vienna	1,094
Casey	2,890	Manito	1,093
Knoxville	2,560	Stonington	1,076
West Dundee	2,530	St. Francisville	1,040
Manteno	2,225		

TABLE II. Correlation coefficients of population with retail sales tax receipts.

	Categories of Retail Sales									
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
Dispersed City.	.99	.80	.98	.94	.88	.95	.79	.98	.93	.97
Sample groups										
A	.97	.91	.92	.82	.93	.92	.54	.95	.93	.96
B	.92	.77	.93	.91	.77	.81	.51	.86	.85	.71
C	.98	.94	.98	.89	.80	.94	.82	.89	.97	.97
D	.92	.86	.97	.92	.73	.93	.87	.71	.95	.98

Identification of categories: I—Total sales tax receipt, II—General merchandise, III—Food, IV—Drinking and eating places, V—Apparel, VI—Furniture, radio, and household goods, VII—Lumber, building, and hardware, VIII—Automotive, IX—Filling stations, X—Other.

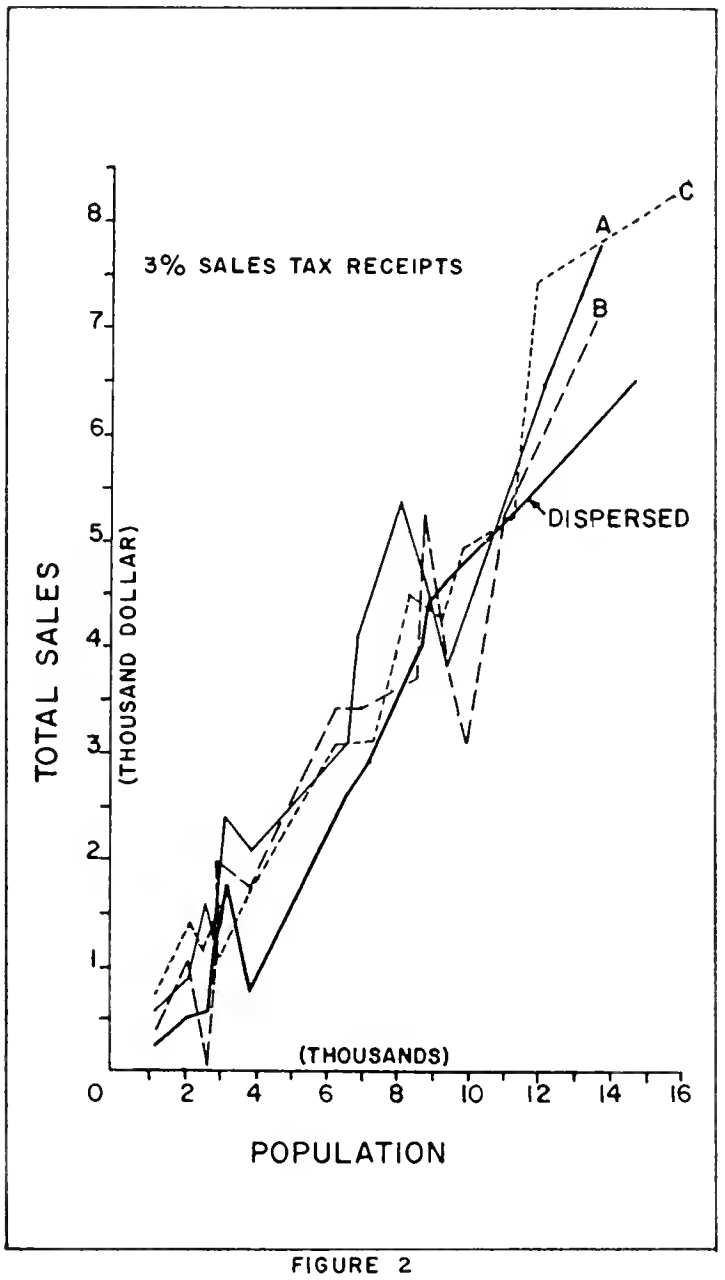

FIGURE 2

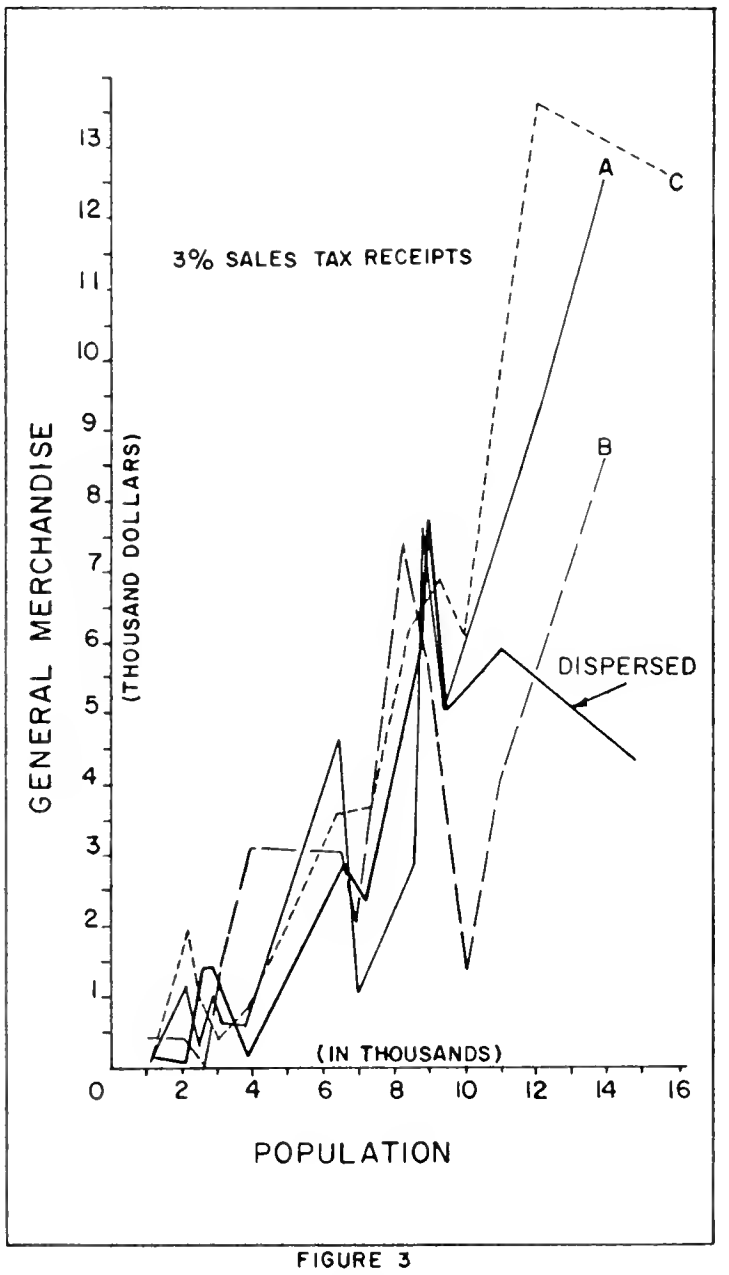

FIGURE 3

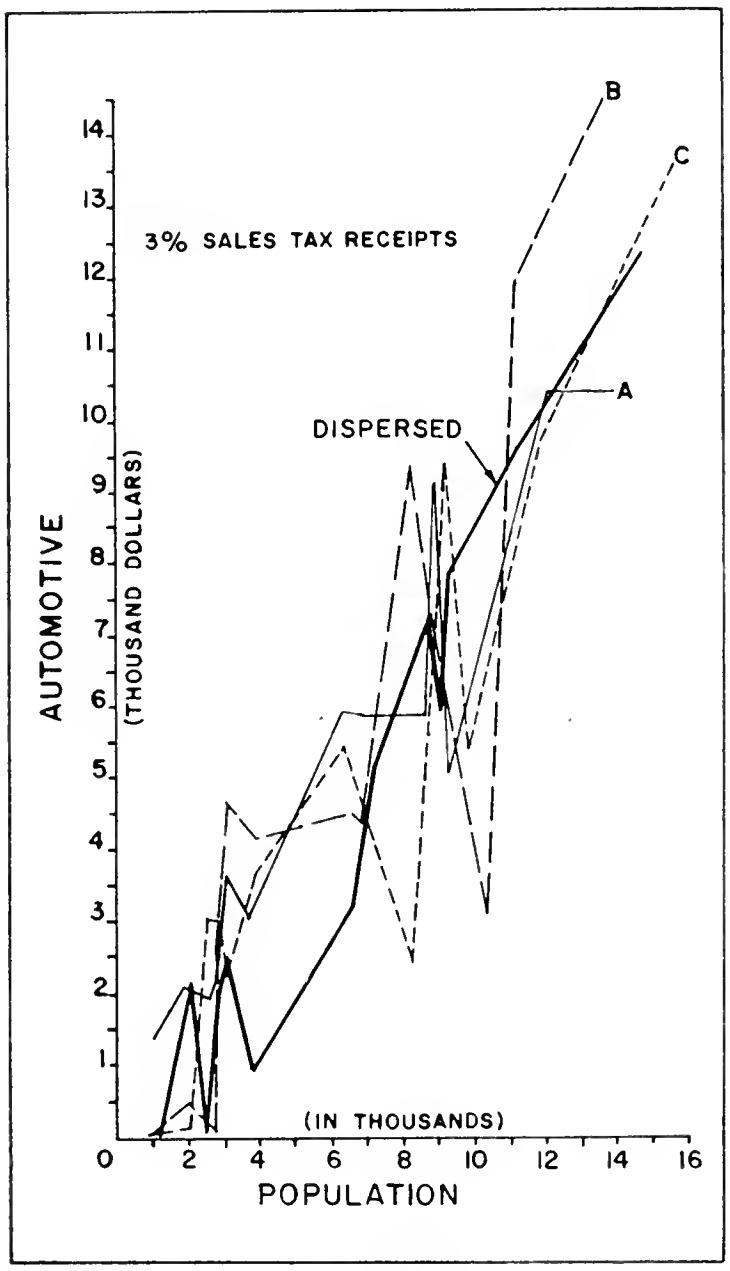

FIGURE 4

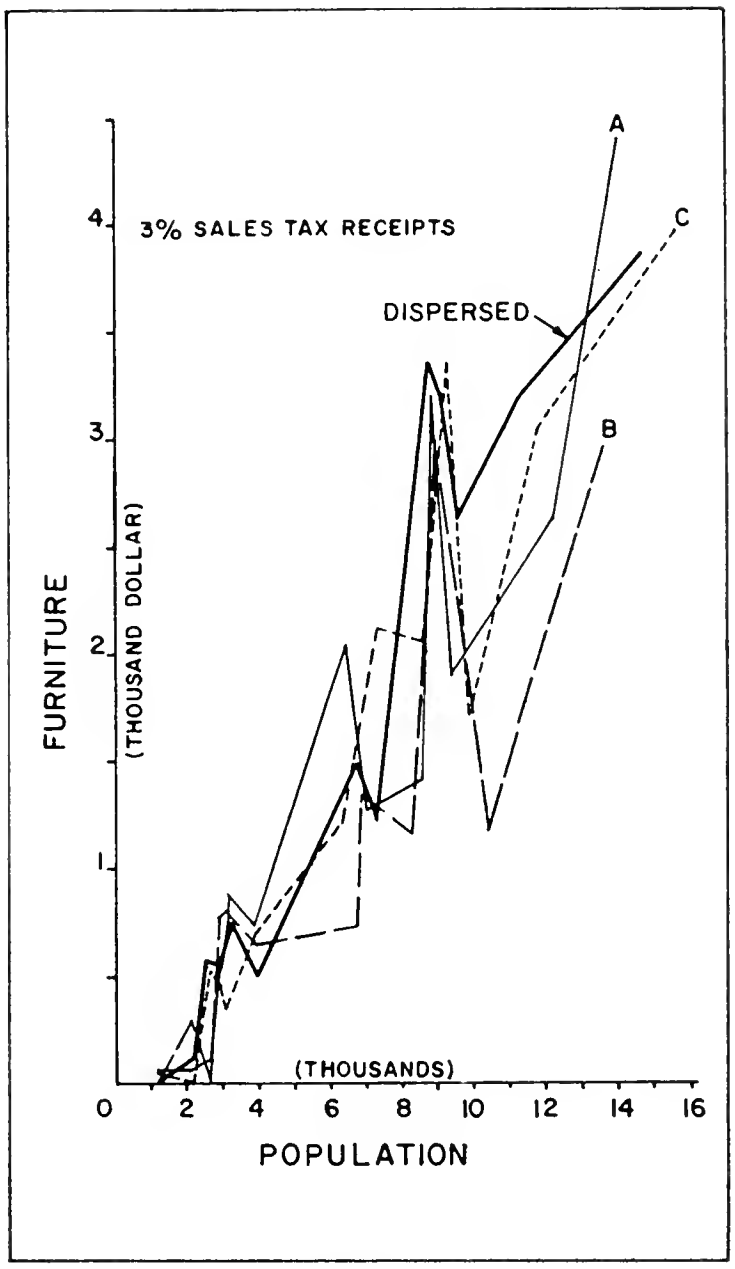

FIGURE 5

than that found in any of the sample groups.

Again using incomparable data, Burton (1959:148-9) found a relatively low degree of association between total population and two types of retail sales — general merchandise and radio, furniture, and household goods. These relationships were cited as evidence of retail specialization based upon inter-action. Yet the use of 1960 figures showed a relationship between radio, furniture, and household goods and total population which was relatively high and failed to differ significantly from the associations found in the sample groups. (Fig. 3) General merchandise also showed a relatively high degree of association with total population in the dispersed city, differing little from the relationships in the sample groups. (Fig. 4)

Examination of additional categories of retail sales which might be considered "non-convenience" goods, and therefore prone to specialization, yielded similar results. Automotive sales showed a very strong correlation with population in the study area (Fig. 5); apparel sales and lumber and building materials also were associated with population in the "dispersed city" to a higher degree than in some of the sample groups.

Summary

The above analysis has indicated that population is very closely related to retail sales in the dispersed city area. Various commodities in which retail specialization seemed likely, are also quite closely correlated with total population. Previous conclusions to the contrary must be attributed largely to the use of incomparable statistics. Furthermore, although earlier workers implied that the retail patterns of the dispersed city were unique, they failed to compare those patterns with others found outside the study area. Such a comparison has yielded little to support the concept that the retail trade patterns of the dispersed city are unique. It is therefore concluded that neither the degree of retail inter-action, nor the uniqueness of the retail trade patterns is sufficient to warrant the amalgamation of thirteen politically discrete cities of southern Illinois into a single unit, known as a "dispersed city".

Acknowledgments

The author would like to express his appreciation to Dr. Howard A. Stafford, Jr., for his helpful suggestions and critical comments made during the preparation of this manuscript, and also to the Mississippi Valley Investigations, under the direction of Dr. Charles C. Colby, for drafting of the graphs used in this paper, and to Joseph Shramovich for drafting the map.

Literature Cited

Beimfohr, O. W. 1953. Some factors in the industrial potential of southern Illinois. Trans. Ill. Acad. Sci., 1946: 97-103.

Burton, Ian. 1959. Retail trade in a dispersed city. Trans. Ill. Acad. Sci. 52: 145-150.

Illinois Retailers' Occupation Tax Returns. 1960. State of Illinois Department of Revenue. Springfield, 30 pp.

SHOPE'S FIBROMA IN ILLINOIS COTTONTAILS

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Shope's fibroma in cottontail rabbits, *Sylvilagus floridanus*, has been found frequently in states east of the Mississippi (Herman, Kilham, and Warbach, 1956) but to our knowledge, this is the first time it has been reported from Illinois. Although experimental transmission of the virus by fleas, (Kilham and Woke, 1953) mosquitoes, (Dalmat, 1959; Dalmat and Stanton, 1958; and Kilham and Woke, 1953) reduviid bugs, (Dalmat, 1959) and bedbugs (Dalmat, 1959) has been accomplished, the life cycle, reservoir and vector complex of the natural disease are not yet known.

To gain a better understanding of potential vectors and other aspects of the epizootiology of fibromatosis, an investigation of the prevalence of fibromas in cottontails from two different habitats was undertaken. The first habitat (in Allerton Park near Monticello, Illinois) was basically sylvan, with thick woods and fallow fields, but with no cultivated land. The second habitat was basically campestral, composed of agricultural fields almost completely devoid of woody cover. It consisted of cultivated fields in Piatt and three nearby counties.

Acknowledgment

Thanks are due Dr. A. M. Watrach for histologic examination of tumor materials and to Mrs. Marion Watrach for the microscopic preparations. It is also a pleasure to acknowledge the encouragement and suggestions of Dr. Richard E. Shope and Dr. Herbert J. Dalmat.

Materials and Methods

This study was carried out between March 1956 and February 1960.

Rabbits from the sylvan habitat were trapped and shot, largely during the fall and winter months. Those from the campestral habitat were collected each month of the year from Champaign, Piatt, McLean and Ford Counties in central Illinois. A few rabbits from the same type of habitat were included from the southern part of the state. Those from the campestral habitat were collected entirely by shooting.

The fibromas were examined histologically and attempts were made to isolate viruses from them. Tumors from both live and dead rabbits were removed aseptically and triturated either in sterile broth containing 2500 units of penicillin and 2500 micrograms of streptomycin per 0.1 ml of inoculum, or in sterile broth without antibiotics; 0.1 ml of this material was inoculated intradermally into the base of the external ears or the scrotums of domestic rabbits (*Oryctolagus cuniculus*) and cottontails; 0.2 ml were inoculated onto the chorio-allantoic membrane of 9 to 11 day-old embryonating chicken eggs.

Portions of tumors from living and dead rabbits were fixed in 10%

TABLE 1.—Fibromas Found in Rabbits Collected from Sylvan Habitats.

Period	Rabbits Collected	Rabbits with Fibromas
March 1, 1956 to February 28, 1957	261	1
March 1, 1957 to February 28, 1958	344	0
March 1, 1958 to February 28, 1959	381	1
March 1, 1959 to February 28, 1960	268	7*
Totals	1244	9

Prevalence for Period 1956 to 1960: 0.72 per cent.

* Including one rabbit later in 1960.

formalin. Sections were made from these and examined histologically.

Serial passages of the virus were made in cottontails and domestic rabbits as well as in chicken embryos. Tumor materials and membranes from infected chicken embryos were stored at —10 C.

RESULTS

A total of 1,506 cottontail rabbits collected over a 4-year period from the campestral habitats yielded no fibromas. In contrast, 9 infected rabbits were found among 1,244 rabbits collected from the sylvan habitat in the same part of the state (Table 1). The disease was much more prevalent in 1959 than in previous years. A single case was found in 1956, another in 1958, while 7 were found in the winter of 1959-60. While more rabbits were collected from the campestral areas than from the sylvan areas, no fibromas were found in the campestral group.

A study of the seasonal prevalence (Table 2) shows that by far the greatest number of fibromas were found in the fall months. Eight were found during this period, while only one was obtained in the early winter and none in the late winter. The affected rabbits were about equally divided by sex (Table 3). Only one adult female had a fibroma; all others were found on juveniles. Most of the tumors were found on the feet or parts of the legs touching the ground (Fig. 1). One rabbit had a tumor on the left ear and another had one on the nose (Fig. 1). One rabbit had four tumors, two had two each, and the other six had one each.

Serum neutralization tests were carried out on domestic rabbits using convalescent serum kindly supplied by Dr. Richard Shope and also from our own infected rabbits. The supernatant fluid from triturated tumor material centrifuged at 1000 RPM for 10 minutes was allowed to

TABLE 2.—Seasonal Distribution of Fibroma Infections in Rabbits from the Sylvan Habitat.

Season	Rabbits Taken From				Totals		
	Woods		Fallow Fields*		Both Areas		
	Without Fibromas	With Fibromas	Without Fibromas	With Fibromas	Without Fibromas	With Fibromas	Per Cent Infected
March to July	40	0	40	0	80	0	0.00
August to October	162	5	410	3	572	8	1.37
November and December	0	0	408	1	408	1	0.24
January and February	77	0	98	0	175	0	0.00
Totals	279	5 (1.8%)	956	4 (0.4%)	1235	9	0.72

* Uncultivated fields adjoining dense woods.

TABLE 3.—Age and Sex of Rabbits Affected with Fibroma Tumors and Anatomical Distribution of the Tumors.

Date	Sex	Age	Wt. (g)	No. Tumors	Part Affected
10/24/56	M	Juv.	1219	1	Left front foot
9/3/58	M	Juv.	1389	1	Foot
9/2/59	F	Adult	1276	1	Leading edge, left ear
9/24/59	M	Juv.	794	1	Right front foot
9/25/59	F	Juv.	1191	4	Both hind feet Right front foot Right front knee
10/1/59	..	....	....	1	Hind feet
10/7/59	F	Juv.	1361	1	Left hind foot
11/23/59	F	Juv.	1134	2	Left front leg Left hind leg
9/15/60*	F	Juv.	....	2	Nose Left front leg

* Collected after the main period of investigation, but included in 1959 and 1960 figures.

FIG. 1.—Natural Case of Shope's Fibroma in the Cottontail Rabbit. There is a lesion on the nose and another on the fore foot, which is held against the rabbit's body.

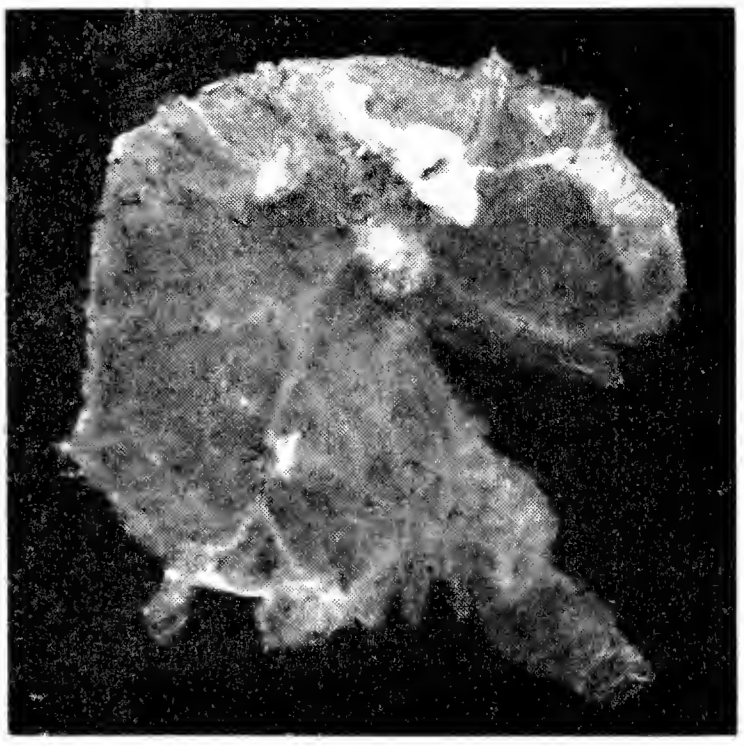

FIG. 2.—Plaques from Shope's Fibroma Virus on the Chorio- Allantoic Membrane of an Embryonating Chicken Egg. (From a color transparency.)

incubate at room temperature with an equal amount of serum for one and one-half hours after which 0.1 ml of the mixture was injected intradermally into the shaven sides of young domestic rabbits. An equal amount of the triturate diluted to the same extent with sterile saline was inoculated into the other side of the rabbit. In addition, rabbits of various ages were inoculated individually with the virus or with the virus-antigen mixture. Additional controls consisted of rabbits inoculated with normal rabbit tissue suspension. Both the homologous serum and serum supplied by Dr. Shope neutralized the virus as shown by the appearance of fibromas on

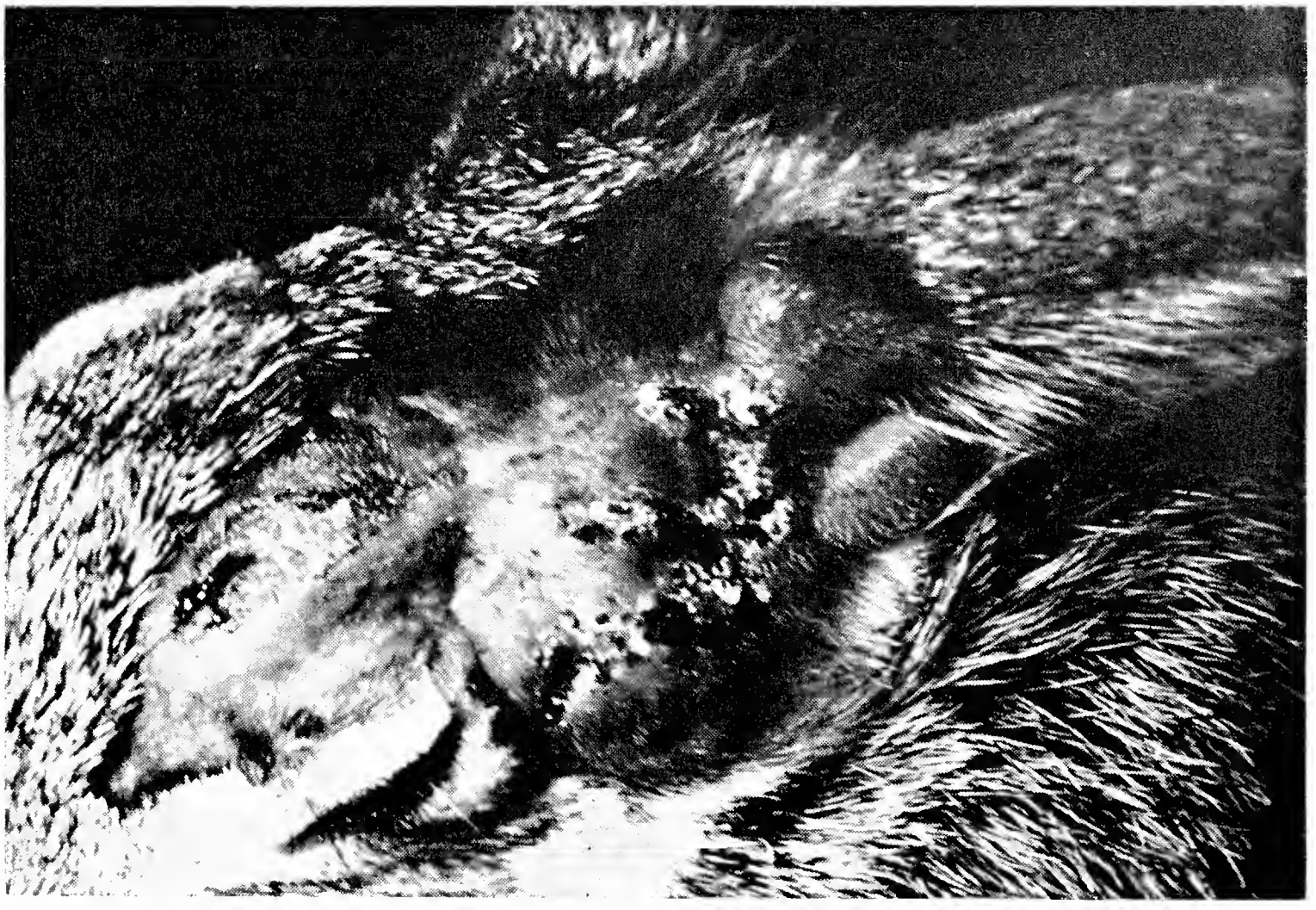

FIG. 3.—Shope's Fibroma on the Ear of Cottontail. The lesion above resulted from intradermal inoculation of triturated fibroma material into the ear of a cottontail and is typical of first, second and third passage lesions.

all sites where the virus alone was inoculated. No fromas appeared where the antibody-antigen mixture, as described above, was inoculated or in those rabbits receiving the normal tissue-saline inoculation.

Histologic examinations were made of 2 field cases and three experimentally infected animals. In all cases tissue changes characteristic of Shope's fibroma were found. Numerous inclusion bodies were seen in epithelial cells of the tumor. The virus was transmitted easily to 11 day-old embryonating chicken eggs, but less easily to 9 day-old chicken embryos. Serial passages in 10 and 11 day-old embryonating eggs were made. The virus did not kill the embryos but both large and small plaques formed on the chorio-allantoic membranes (Fig. 2). The infection was readily transmitted to domestic and wild rabbits (Fig. 3). In young domestic rabbits the tumors appeared in 3 to 4 days, reached a peak in 2 weeks and regressed within another 2 weeks. Tumors in cottontails were visible at 8 to 10 days and did not regress for 2 to 3 months or longer. Tumors surgically removed from each species were examined histologically and found to be indistinguishable from those of naturally occurring cases although the gross appearance of the experimentally induced tumors was different from that of the natural lesions (Figs. 1 and 3).

The virus was readily transmitted from either natural or experimental lesions from the cottontail, but not from the domestic rabbit. When experimentally induced tumors were removed from wild rabbits they were quickly replaced by proliferation of tumor material at the site, but this did not occur in domestic rabbits.

Discussion

The natural mode of transmission of Shope's fibroma remains unknown, although a considerable amount of experimental work has been done on the problem. Analyses of the data, correlated with the findings reported here may give clues for further research. The largest previous investigation was done by the Rose Lake Wildlife Experiment Station in Michigan (Annual Reports, 1940-41, 1941-42, 1942, 1943, 1944, 1945). Lesions were found in 2.7% of 1071 rabbits examined between 1940 and 1945. Herman *et. al.* (Herman, Kilham, and Warbach, 1956) found 4.1% of 359 Maryland rabbits at the Patuxent Research Refuge involved between 1947 and 1953. Reilly (Herman, Kilham and Warbach, 1956) found 8.5% of 174 rabbits from the Three Rivers Game Management Area, Baldwinsville, N. Y. with fibromas in 1953.

From the standpoint of numbers and regularity of collection this investigation was biased in favor of finding more fibromas in rabbits from the campestral habitats. That fibromas were found in rabbits only from the wooded terrain suggests the possibility of a sylvan vector or reservoir.

Dalmat (Dalmat, 1959) found the following mosquitoes capable of transmitting the fibroma virus under laboratory conditions: *Ades aegypti, A. triseriatus, Culex pipiens* and *C. quinquefasciatus. Aedes aegypti* is found only in such sites as warehouses in Illinois and then only oc-

casionally. The other species mentioned are common throughout the state. The flying range of the three species is such that they were probably present in both habitats during the period of study. It is possible that the sylvan habitat might have had larger numbers of *Aedes triseriatus,* the treehole mosquito. Field records show that mosquitoes did not appear to be more numerous in the sylvan habitat than in the campestral. The bedbug, *Cimex lectularius L* is found throughout the state, but has not been recorded as an ectoparasite of cottontails (Shope, 1959). No triatoma bugs have been reported in central Illinois. The two fleas which were used primarily in the experiments of Kilham and Woke, (1953) *Cediopsylla simplex* and *Odontopsyllus multispinosus,* are found on Illinois cottontails. The former (the common eastern rabbit flea) was far more abundant. It was found in abundance on rabbits of both habitats throughout the year. Cottontails of central Illinois are occasionally parasitized by the following chiggers: *Euschŏngastia peromysci* (Ewing), *Trombicula (Eutrombicula) alfreddugesi (Oudemans)* and *Trombicula (Neotrombicula) whartoni* (Ewing). The species used unsuccessfully in transmission by Dalmat (Dalmat, 1959), *Trombicula splendens,* has not been reported from Illinois cottontails.

The continental rabbit tick, *Haemaphysalis leporispalustris* (Packard) (Herman, 1938) is another common ectoparasite of Illinois cottontails; it is also the chief carrier of *Pasteurella tularensis,* which has in the past caused mortality among cottontails of this state (Stannard and Pietsch, 1958). Adults are found on the cottontails largely from March to June. Nymphs have two peak periods, one in May and another in September and October. The peak for the larvae comes in August and September, at which time the cottontails are more heavily parasitized with larvae and nymphs than in the spring. Since Larson *et. al.* (Dalmat, 1958) were able to transmit rabbit papillomatosis virus by nymphs of the rabbit tick, this arthropod should also be considered as a possible vector.

In correlating the experimental findings with this investigation, it would appear that, with the exception of *Aedes triseriatus,* mosquitoes are not the major suspects in spite of their proven capability in the laboratory. The experimental evidence in favor of fleas is much less extensive; from the abundance of fleas on cottontails at all seasons of the year in both habitats, it would appear that they are not the vectors in central Illinois. Population peaks of the rabbit tick nymph and larva as determined by a previous investigation in northern Illinois correlated well with the prevalence of Shope's fibroma in the study reported here. However, few ticks were encountered in these collections and no differences between the two habitats in this respect were recorded. There is a strong possibility that more larval ticks would be found in the sylvan habitat if efforts were made to find them.

The location of the lesions favors the assumption that the vector reaches the rabbit by way of the

ground. The sites of all except two lesions were on the feet or legs as shown in Table 3. One was on the nose and one on the ear. Chigger mites are usually found in Illinois cottontails on, or in, the ears (Stannard and Pietsch, 1958). Lesions caused by fleas, mosquitoes and reduviid bugs appeared on other parts of the body in the experimental disease. There is also the possibility that another animal found in sylvan habitat may be the reservoir of the virus. Tumors similar to or even immunologically related to Shope's fibroma have been found on other animals (Herman and Bigchoff, 1950; Herman and Reilly, 1955; and Kilham, Herman and Fisher, 1953), including deer, grey squirrels, fox squirrels, woodchucks and porcupines.

Subdivision of the sylvan habitat into dense woods and the immediately adjoining fallow fields in Table 2, yielded differences which were not so striking as those between the agricultural and wooded areas. Approximately 1.8% of 279 rabbits from the woods had fibromas while only about 0.4% of 956 rabbits from the uncultivated fields were affected. This is another indication that the wooded area might have been the major habitat of the vector or reservoir. The seasonal prevalence of the disease in Illinois supports the hypothesis that an arthropod vector is responsible, since the large majority of cases were found in the fall. There is an abrupt diminution in the number of tick larvae and nymphs found on rabbits after frost (Shope, 1959). The few cases found in early winter are readily explained on the basis of the time required for the regression of natural lesions, which can be at least 10 months (Shope, 1959). It is also possible that under certain circumstances a few vectors might live into the winter months.

The age distribution of the affected rabbits in Table 3 was one adult to 8 juveniles. This is approximately the proportion of juveniles to adults found in the fall and winter. Ninety-two per cent of the rabbits trapped in these months were juveniles.

The differences between the prevalence of Shope's fibroma in cottontail rabbits on cultivated fields and from heavily wooded habitats indicate that foci of the disease in central Illinois are to be found in the wooded regions.

Summary

An investigation of Shope's fibroma in cottontail rabbits was carried out between 1956 and 1960 in central Illinois. Nearly 3,000 cottontails, largely from four adjoining counties, were examined at monthly intervals. A total of 1,506 cottontails from cultivated fields were negative; in contrast, 0.72% of 1244 rabbits taken during the same period from a heavily wooded area were positive. A much larger proportion of the positives were taken from dense woods than from nearby uncultivated fields. All fibromas except one were found on body parts usually or frequently in contact with the ground. All but one case were found in the fall; the exception was found in early winter.

Literature Cited

Dalmat, H. T. 1959. Arthropod transmission of rabbit fibromatosis (Shope). J. of Hyg., 57:1-32.

Dalmat, H. T. 1958. Arthropod transmission of rabbit papillomatosis. J. of Exp. Med., 108:9-20.

Dalmat, H. T. and M. F. Stanton. 1958. A comparative study of the Shope fibroma in rabbits in relation to transmissibility by mosquitoes. J. of Natl. Cancer Institute, 22:593-615.

Herman, C. M. 1938. Occurrence of larval and nymphal stages of the rabbit tick, *Haemaphysalis Leporis-Palustris*, on wild birds from Cape Cod. Bull. of the Brooklyn Entomological Soc., 33(3):133-134.

Herman, C. M., and A. I. Bischoff. 1950. Papilloma, Skin Tumors in Deer. California Fish and Game, 36:19-20.

Herman, C. M., L. Kilham and O. Warbach. 1956. Incidence of Shope's rabbit fibroma in cottontails at the Patuxent Research Refuge. J. of Wildlife Management, 20: 85-89.

Herman, C. M. and J. R. Reilly. 1955. Skin tumors on squirrels. J. of Wildlife Management, 19: 402-403.

Kilham, L., C. M. Herman and E. R. Fisher. 1953. Naturally occurring fibromas of grey squirrels related to Shope's rabbit fibroma. Proc. Soc. Exp. Biol. and Med., 82:298-301.

Kilham, L. and P. Woke. 1953. Laboratory transmission of fibromas (Shope) in cottontail rabbits by means of fleas and mosquitoes. Proc. Soc. Exp. Biol. and Med., 83:296-301.

Rose Lake Wildlife Experiment Station, Michigan. 1940-45. Dept. of Conservation, Annual Reports: 2nd (1940-41); 3rd (1941-42); 4th (1942); 5th (1943); 6th (1944); and 7th (1945).

Shope, R. E. 1959. The roles of virus and host in determining the host reaction to the fibroma-myxoma virus complex. Genetics and Cancer, Texas, pp. 311-323.

Stannard, L. J. and L. R. Pietsch. 1958. Ectoparasites of the cottontail rabbit in Lee County, northern Illinois. Natural History Survey Publication, Urbana, Illinois, Biological Notes, 38:1-19.

CEREBROID OOLITES

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The oolitic deposits along the shores of the Great Salt Lake, Utah described by Eardley (1938) do not seem to have attracted the attention they deserve as remarkable examples of application of the principle of uniformitarianism.

These sediments display several peculiar types of oolites, the equivalent of which occur in the geological column. Among them are the broken and regenerated oolites described from limestones and iron ores which may be seen forming today along the shoreline deposits of the Great Salt Lake as the result of reciprocal mechanical impacts (Carozzi, 1961).

The present paper describes and discusses the significance of the so-called "cerebroid oolites" also forming at the present time and frequently reported in the Ste. Genevieve Formation (Mississippian) of Illinois and adjacent states.

Oolitic deposits of the Great Salt Lake, Utah. Our investigation of the Great Salt Lake oolitic deposits has revealed six distinct types of oolites. These are:

1. Spherical body with pearl-smooth surface showing in section regular and fine concentric rings of impure aragonite consisting of small radial needles with interstitial clay minerals (Fig. 1,A). These layers are developed around nuclei of detrital minerals or faecal pellets of brine shrimps. This is the original type of oolite as formed in the shallow and gently agitated waters of the Great Salt Lake mainly from June to November (Eardley, 1938: 1327-8).
2. Spherical body with pearl-smooth surface showing in section a few concentric layers of impure aragonite coating an internal spherical part which is calcitic and displays an interference between fibro-radiated and concentric structures (Fig. 1,B). This is the incipient result of the inversion to calcite and of the recrystallization which takes place from February to May in correspondence with the period of maximum inflow during which the resulting dilution of the waters generates conditions of little or no precipitation of calcium carbonate. In these oolites the inversion and recrystallization processes have not yet affected the newly deposited aragonite layers. The central portion of calcite shows small prismatic crystals in radial position and usually limited to a given concentric layer. The degree of recrystallization is rather uniform, however some radial areas are better crystallized than others but their distribution is random and different from one layer to another. The outside shape of the recrystallized central part is not appreciably affected and remains spherical.
3. Spherical body with finely granular and crystalline surface ap-

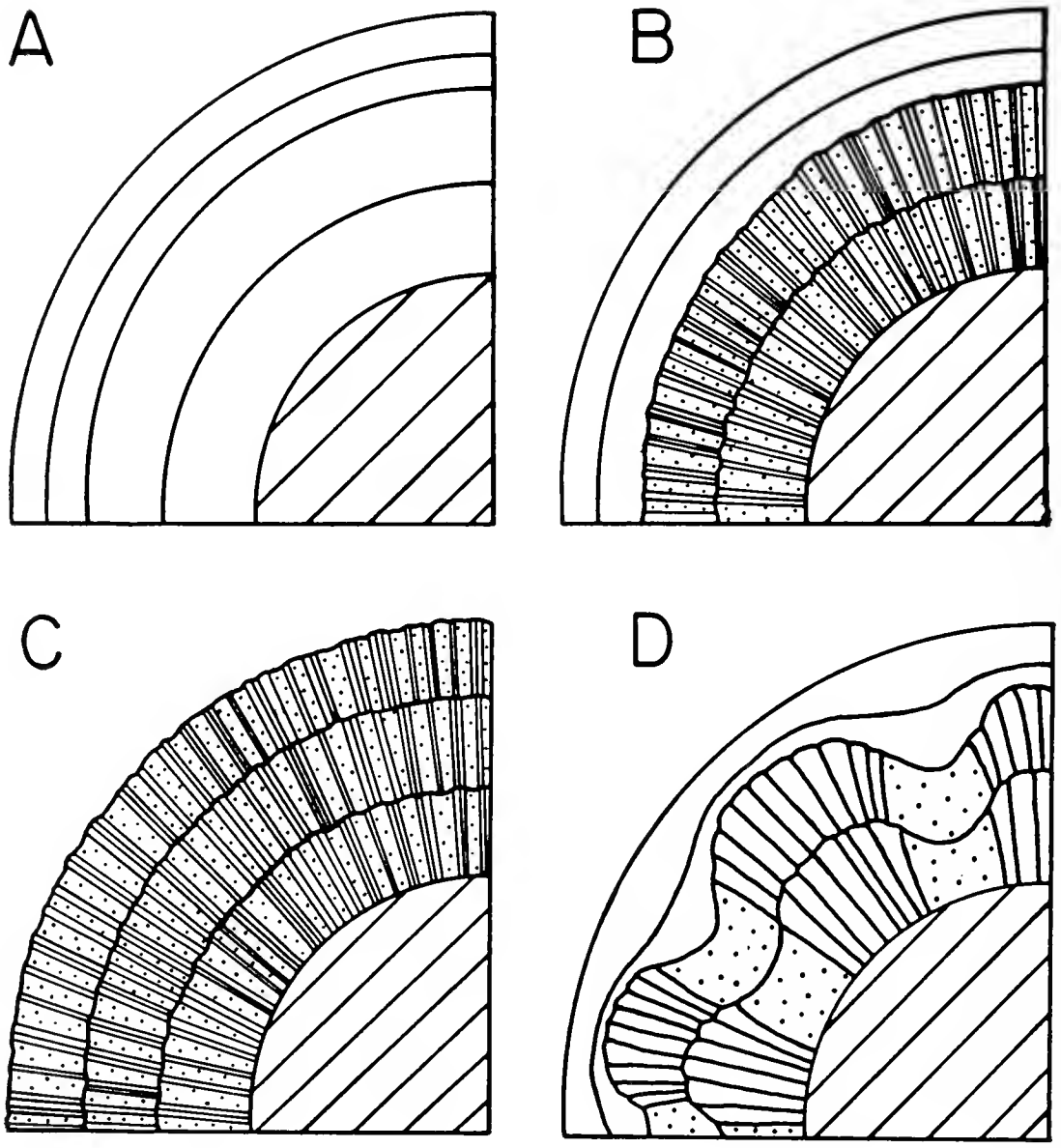

FIGURE 1. Schematic segments of the six types of oolites occurring in the present deposits of the Great Salt Lake, Utah.
A: aragonitic oolite with normal concentric rings
B: aragonite concentric rings over fibro-radiated calcite
C: calcitic oolite entirely fibro-radiated
D: aragonite concentric rings over cerebroid calcite
E: calcitic oolite entirely cerebroid
F: cerebroid calcite over fibro-radiated calcite

pearing in section as entirely calcitic and displaying an interference between fibro-radiated and concentric structures (Fig. 1,C). This is the completed stage of the preceding type.

4. Spherical body with pearl-smooth surface showing in section a few concentric layers of impure aragonite of variable thickness coating an internal portion of calcite displaying an interference between a peculiar type of fibro-radiated structure and the original concentric one. This interference generates a festooned or "cerebroid" outline (Fig. 1,D) which consists of juxtaposed convex and concave segments corresponding to the alternation of radial bundles of clear calcite with darker areas of cryptocrystalline calcite.
5. Mottled and speckled spherical body resulting from numerous light-colored and well-crystal-

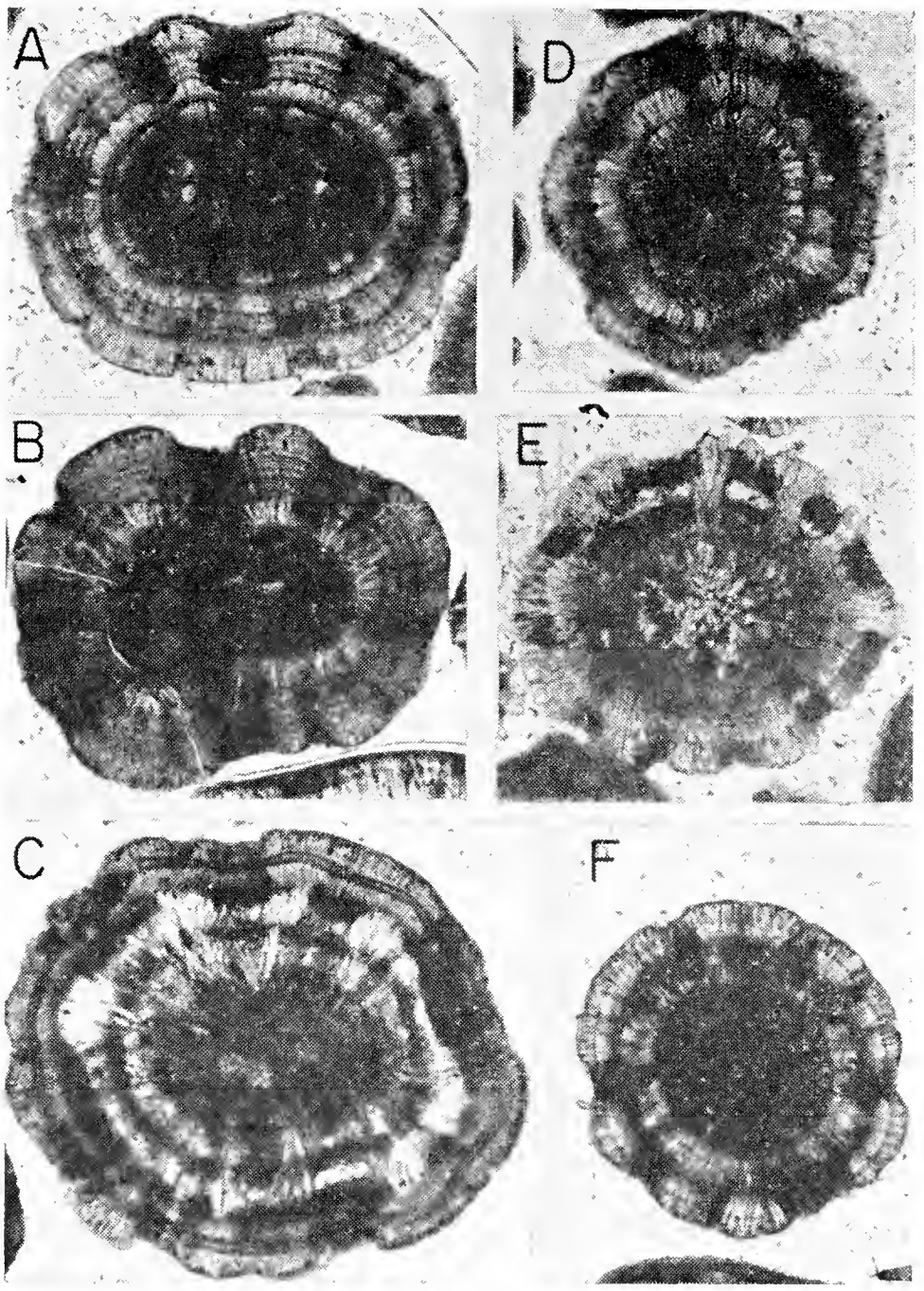

FIGURE 2. Cerebroid oolites from the present deposits at the northern tip of Stansbury Island, Great Salt Lake, Utah. Nicols not crossed, X 88. See text for additional explanations.

lized bulging areas separated by darker and concave zones with cryptocrystalline structure. (Fig. 1,E) In section such an oolite displays a festooned or cerebroid aspect representing the completed stage of the preceding type. These bodies have been described by Eardley (1938: 1380-84, pl. 8, 10 a, 12 b) under the name of "mottled oolites" and are the main subject of the present paper.

6. In this last type (Fig. 1,F), the bundles of clear calcite crystals, instead of originating at the nucleus boundaries, start on top of one or several concentric layers displaying uniform fibro-radiated structure.

Description of cerebroid oolites in the Great Salt Lake deposits. Typical sections of cerebroid oolites show, starting from the nucleus or from a given concentric ring, wedge-shaped bundles of radial crystals of clear calcite (Fig. 2,A and B) or occasionally single wedge-like crystals (Fig. 3,C and E). Both types reach the external surface where they distinctly protrude as flat-topped or convex bulges displaying often a well-developed fan-shaped structure (Fig. 2,C and E).

The bundles of clear calcite fibers are composite structures which increase irregularly in width toward the outside of the oolite and consist of a superposition of constricted and expanded segments with straight or fan-shaped boundaries (Fig. 2, C; Fig. 3,D). These segments always correspond to the intersection with a given concentric ring or a particular set of them. In some of the more constricted parts, the prismatic bundles may be reduced to a few fibers of calcite or even to a single one. The modifications of section of the bundles express actually a variable lateral extension of the prismatic recrystallization which may in some cases develop laterally far enough to join adjacent prismatic areas along one or several concentric rings.

Inside the bundles of clear calcite crystals are abundant narrow and irregular radial zones of cryptocrystalline calcite also closely related to the intersection with given concentric layers (Fig. 3,G). Some of these radial zones appear limited to the basal portion of the bundles and wedge out toward the outside whereas others indent the terminal parts of the bundles which appear as irregularly crenulated. These darker areas contain a concentration of impurities, particularly clay minerals which also line the boundaries of many prisms as discontinuous films. Most of the bulging areas are irregularly convex and some of the flat-topped ones not corresponding to single crystal terminations may have undergone a slight abrasion.

It is important to point out for the understanding of the genesis of the cerebroid oolites that in the bundles of clear calcite fibers the original concentric rings are wider than in the adjacent areas and their boundaries appear as "ghost lines" displaced toward the outside with *an increased curvature* (Fig. 2,A; Fig. 3, D and G).

The intermediate radial spaces between the projecting bundles of clear calcite consist of dark cryptocrystalline calcite containing an ex-

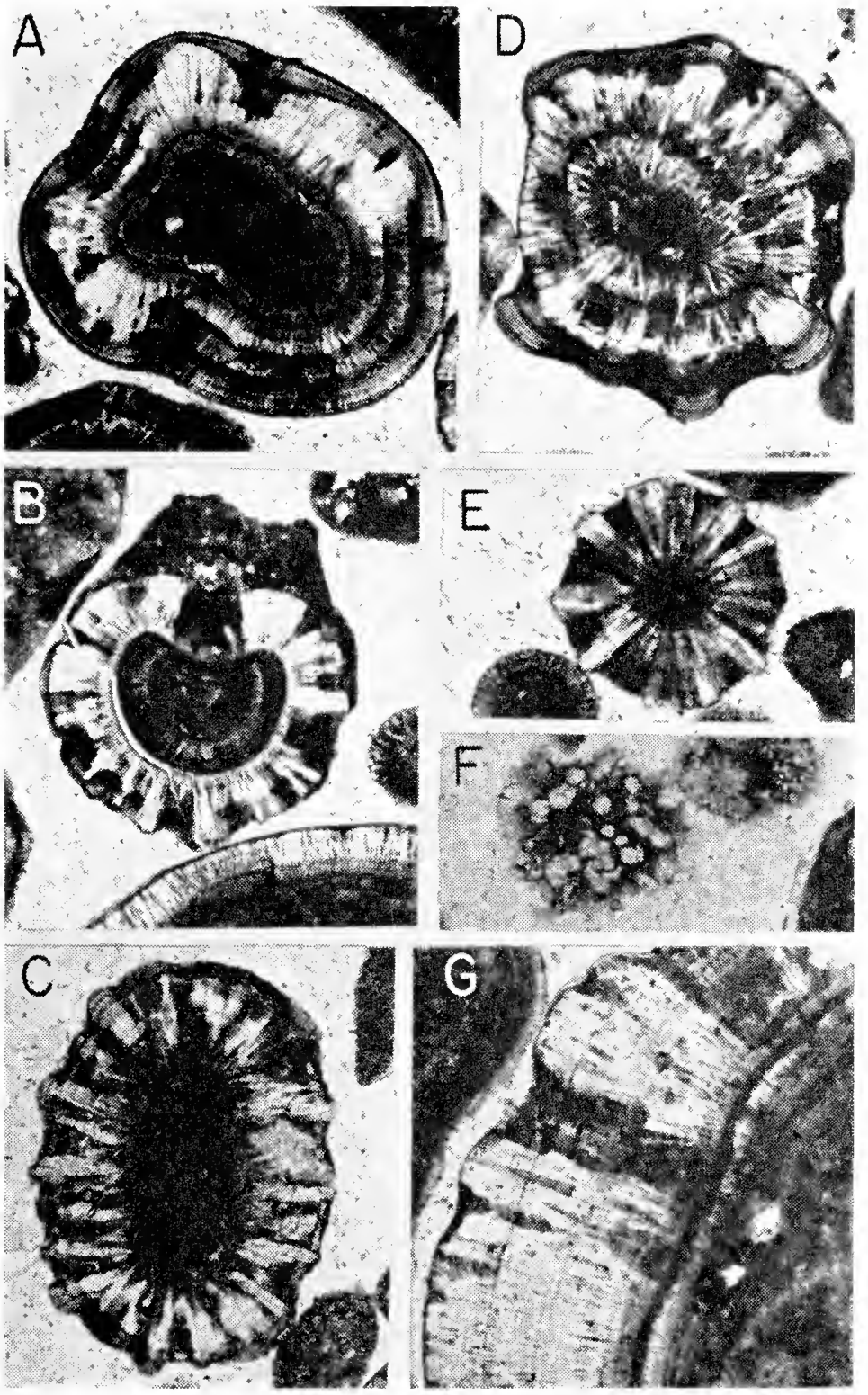

FIGURE 3. Cerebroid oolites from the present deposits at the northern tip of Stansbury Island, Great Salt Lake, Utah. Nicols not crossed, B and D :X 55, all the others X 88.
A: concentric rings of aragonite over cerebroid calcitic core
B: broken and recoated oolite
C and E: wedge-like calcite crystals
F: tangential section
G: details of cerebroid structure

cess of impurities and clay minerals. In these darker areas the original concentric rings are barely visible, they are in a depressed position, thinner compared to those preserved in the prismatic bundles and *concave* toward the outside (Fig. 2, A; Fig. 3, A and G). The shape of the cryptocrystalline areas is actually a function of the adjacent bundles being either conical with the apex directed toward the outside of the

oolite, or straight or irregular.

The darker zones may be occasionally interrupted by recrystallized concentric rings when the prismatic crystals of the bundles spread laterally and eventually join. The peripheral boundary of the darker areas is not always a regularly curved line parallel to the concave concentric rings, but is quite irregular and cuts across some of the thinnest concentric laminae indicating that some solution or abrasion has taken place (Fig. 3,G).

It is not possible to determine the reason for the localization of the bundles of clear calcite crystals particularly in oolites with well-rounded cores where they seem to be quite regularly spaced. In oolites with irregular cores, the bundles are definitely located in greater proportion on the protruding areas of the nuclei which display the smallest radii of curvature. In both cases, the final result in cross-section is to change the original circular outline of the oolite into a cerebroid one consisting of a juxtaposition of light-colored convex areas and dark-colored concave ones.

Formation of cerebroid oolites in the Great Salt Lake deposits. The sections across cerebroid oolites indicate that they result from a type of fibro-radiated recrystallization which, instead of being uniformly distributed in the spheroidal bodies, has preferentially taken place along certain radii generating wedge-like bundles of calcite fibers.

Let us consider one layer of impure aragonite deposited by the oolitization processes over a nucleus

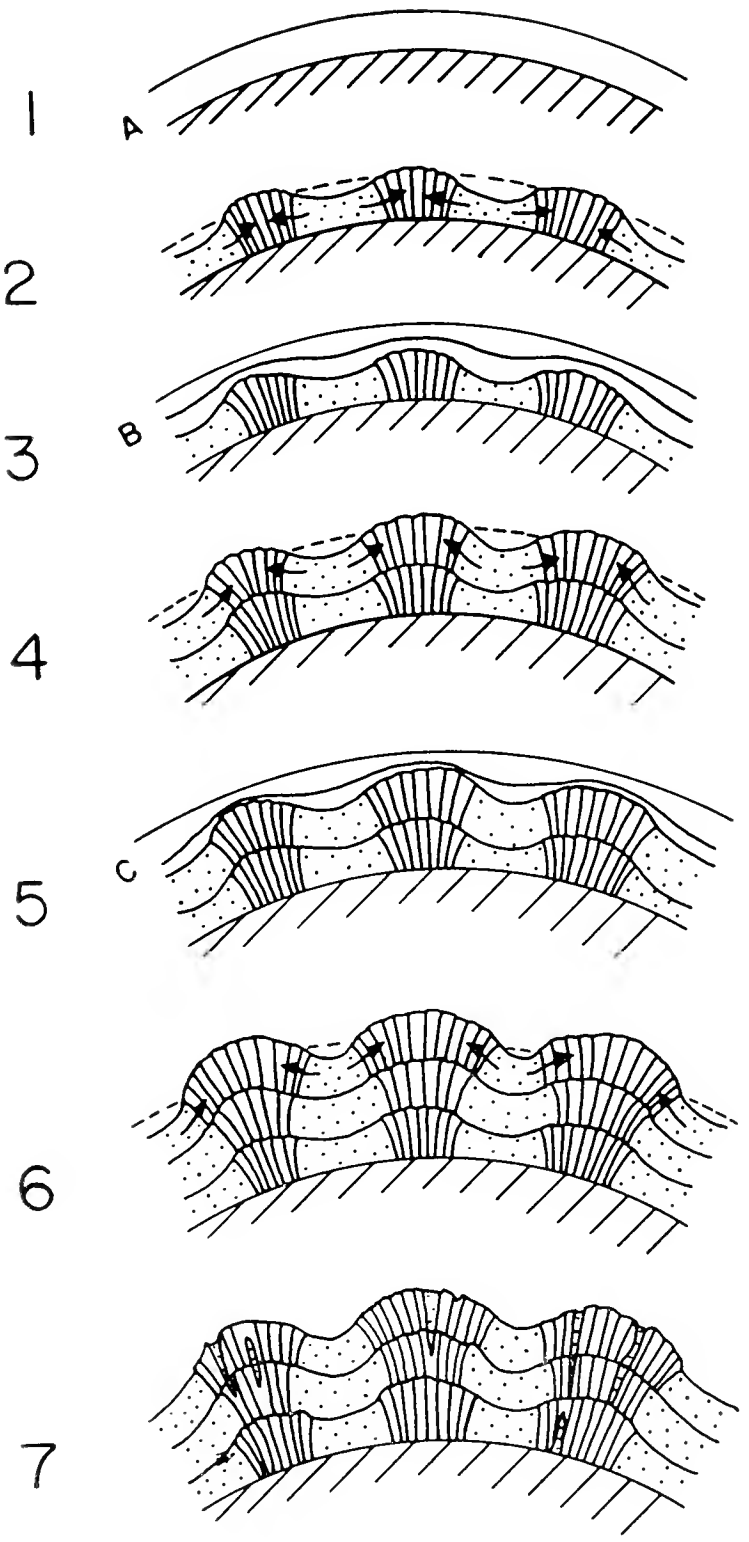

Fig. 4.—Diagrams illustrating the formation of the cerebroid structure in the oolites of the present deposits of the Great Salt Lake, Utah.

The aragonite layers (A, B and C) are left blank, the bundles of prismatic calcite alternate with dark areas of cryptocrystalline calcite (stippled). See text for additional explanations.

and inverting to calcite (Fig. 4, stage 1). The growth of the bundles of radial crystals corresponds to an expansion of the original layer at these particular places expressed by

an increased curvature and peripheral bulging (Fig. 4, stage 2).

Such a process of local growth requires an addition of calcite which has taken place at the expense of the adjacent cryptocrystalline areas which contain an addition of clay impurities expulsed by the growth of the calcite fibers. Since the loss of calcite predominates in the darker areas over the addition of impurities, a decrease of volume has taken place in them accompanied by a partial destruction of the original concentric structures. This exchange is demonstrated by the thinning of the original concentric layers which become concave outwards (Fig. 4, stage 2).

The final result of this process of segregation during which clear calcite crystals have grown along certain radii and impurities have been concentrated in the poorly crystallized intermediate areas, is to change the original circular outline of the concentric rings into a juxtaposition of convex and concave segments expressed in the cerebroid aspect (Fig. 4, stage 2).

This differential recrystallization into fibro-radiated bundles apparently takes place from February to May. It corresponds to the time of maximum inflow in the Great Salt Lake during which the related dilution of the waters allows little or no precipitation of calcium carbonate; solution of the smallest crystals could even take place (Eardley, 1938: 1373). This solution would account for some of the peripheral irregularities of the darker cryptocrystalline areas described above. Agitation and rolling around of the oolites during the same period could also be responsible for slight erosion in the same poorly crystallized depressions as well as for the flat-topped ends of some calcite bundles.

The differential fibro-radiated recrystallization appears completed before deposition of the next set of aragonite layers during the following June to November period (Fig. 4, stage 3). These new layers of impure aragonite have a tendency to re-establish spherical outlines and are normally thicker above the concave areas and thinner over the bulges.

During the following winter-spring season, inversion to calcite and recrystallization of these new concentric layers take place. The underlying prismatic bundles offering better conditions for renewed growth than the poorly crystallized intermediate areas, the new groups of calcite prisms tend to grow in the same particular places as the underlying ones but with a variable width related to the properties of the concentric layers involved. In such a manner, the cerebroid structure is perpetuated from one set of layers to the overlying one (Fig. 4, stage 4).

The process just described is then repeated after deposition of every set of aragonite layers with possible intermediate episodes of slight erosion or solution and new segments are added to the composite bundles of calcite fibers (Fig. 4, stages 5 and 6). As mentioned above, the latter are in fact quite complex and contain numerous radial patches of poorly crystallized material (Fig. 4, 7).

In conclusion, cerebroid oolites in the Great Salt Lake deposits result from the seasonal alternation of summer-fall periods of oolitization with winter-spring periods of inversion to calcite and differential fibro-radiated recrystallization. It is possible that the inversion of aragonite to calcite may have no genetic relation with the cerebroid structure which could then develop also in oolites originally calcitic.

The rapid internal change of the oolites from a concentric to a predominant radial structure of any kind is of great interest because it explains the shape of broken and regenerated oolites found in the Great Salt Lake deposits as well as in the geological column (Berg, 1944; Carozzi, 1961). In both instances oolites undergoing mechanical impacts during reworking processes penecontemporaneous with deposition are broken in most of the cases in clean-cut halves or quarters of spheres indicating a stronger control of the fibro-radiated structure over the concentric one in the pattern of rupture.

Description of cerebroid oolites in the Ste. Genevieve Formation (Mississippian). To our knowledge cerebroid oolites have been reported for the first time in the Fredonia Member of the Ste. Genevieve Formation of Southern Illinois by Graf and Lamar (1950: 2327, Fig. 7), and their interpretation will be discussed later.

The specimens described in this paper have been collected from the Levias Member of the Ste. Genevieve Formation on the east wall of a road cut on the northbound lane of Interstate Route 37, SW ¼ sec. 6, T.13 S, R.1 E, three miles north of Dongola, Illinois. The particular limestone containing the cerebroid oolites is the basal bed of the Levias Member and corresponds to unit 7 of stop 7, of the 25th Annual Tri-State Geological Field Conference (Harris, 1961).

In general cerebroid oolites are rather rare in the Ste. Genevieve oolitic limestones and this applies to the investigated bed in which they represent never more than 2 to 5% of the total number of oolites present in a given thin section. The Mississippian cerebroid oolites display all the major characters of those described above from the Great Salt Lake and their detailed description appears superfluous. However a few small differences may be noticed (Fig. 5). The prismatic bundles do not appear so well crystallized in spite of their distinct peripheral bulging as they are in the specimens from the Great Salt Lake and also they do not show accentuated constrictions and expansions. This last observation indicates that the superposed concentric layers were rather uniform in original composition and structure.

It is interesting to mention here that one calcitic oolite with an outer shell of concentric rings coating a central portion with cerebroid outline has been described from the Rogenstein of Vienenburg, Germany (Berg, 1944: 48, Fig. 67). In this specimen similar to our type 4 of the Great Salt Lake deposits, the fibro-radiated structure has clearly affected the deposition of the last set of concentric rings. More recent-

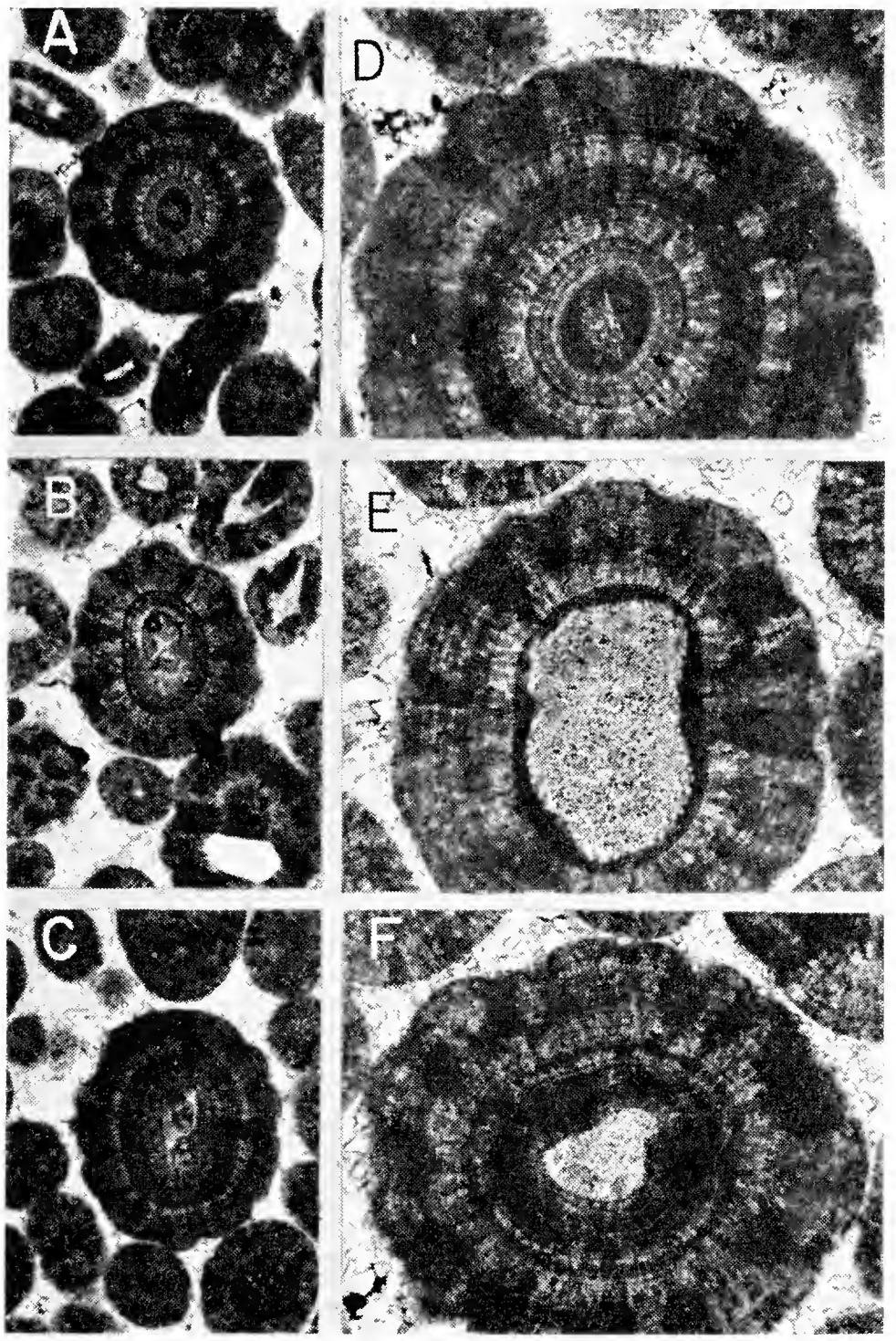

FIGURE 5. Cerebroid oolites from the Levias Member, Ste. Genevieve Formation (Mississippian), Dongola, Illinois. Nicols not crossed, A to C: X 22, D to F: X 55.

ly Usdowski (1962: 167, Fig. 20) described oolites with "Kegelstruktur" from the Lower Buntsandstein of Northern Germany which somewhat resemble cerebroid oolites. He assumed for their formation the existence of several nuclei which would have interfered during growth. This mechanism does not seem to apply to the oolites discussed in this paper.

Formation of cerebroid oolites in the Ste. Genevieve Formation (Mississippian). In their original description Graf and Lamar (1950: 2327, Fig. 7) considered the cerebroid oolites to result essentially from a marginal replacement of the brown calcite of the oolites by the interstitial clear calcite. However they also assumed that a few broader arcs of the oolite margins might be

of primary origin or due to compaction effects.

In the light of the observations of Berg (1944) and of the preceding description it is difficult to visualize a replacement mechanism because the cerebroid outline is not a superficial feature but only the peripheral expression of an internal modification of the oolites. Indeed many oolites display marginal irregularities reaching a depth of 0.1 mm or more attributable to mechanical impacts during deposition, or replacement by the interstitial cement or compaction. However the designation of cerebroid should be restricted to those owing their peculiar festooned shape to differential fibro-radiated recrystallization which displays a certain number of transitional terms to uniformly fibro-radiated types as would be expected whenever the bundles of radial calcite are poorly developed.

On the basis of the evidence from the Great Salt Lake deposits, it is suggested that the cerebroid structure is generated during phases of interruption of the accretion process and consequently before any precipitation of clear interstitial calcite.

The abundance of cerebroid oolites (30 to 50% of the oolites in a given thin section) in the Great Salt Lake deposits compared to the relatively rare occurrence (2 to 5%) in the Mississippian oolitic rocks may be an expression of the peculiar present-day physico-chemical conditions (high salinity and temperature) in the Great Salt Lake.

Summary

A large proportion of the aragonite oolites forming at present in the Great Salt Lake, Utah display a peculiar type of fibro-radiated structure generated during their seasonal inversion to calcite. The recrystallization instead of being uniformly distributed in the spheroidal bodies has preferentially taken place along certain radii generating wedge-like bundles of clear calcite fibers separated by intermediate areas of dark cryptocrystalline calcite enriched with clay impurities. The final result in cross section is to change the original circular outline of the concentric rings into a juxtaposition of convex and concave segments self-perpetuating from one season to another. The name of cerebroid oolite is applied to these peculiar bodies which are the modern equivalents of similar forms described in the Ste. Genevieve Formation (Mississippian) of Illinois and adjacent states. It is suggested that the differential recrystallization which generated cerebroid oolites in the past may not necessarily have been restricted to oolites originally aragonitic.

Literature Cited

Berg, G. 1944. Vergleichende Petrographie oolitischer Eisenerze. Reichsamt f. Bodenf., Archiv für Lagerstättenforschung, Heft 76, 128 pp.

Carozzi, A. V. 1961. Oolithes remaniées, brisées et régénérées dans le Mississipien des chaînes frontales, Alberta Central, Canada. Archives des Sciences, Genève, 14 (2): 281-296.

Graf, D. L. and J. E. Lamar. 1950. Petrology of Fredonia oölite in South-

ern Illinois. Am. Assoc. Petroleum Geologists Bull., 34 (12): 2318-2336.

EARDLEY, A. J. 1938. Sediments of the Great Salt Lake, Utah. Am. Assoc. Petroleum Geologists Bull., 22 (10): 1305-1411.

HARRIS, S. E., JR. 1961. 25th Annual Tri-State Geological Field Conference Guidebook. Southern Illinois University, Carbondale, Illinois, mimeographed, 28 pp.

USDOWSKI, H. E. 1962. Die Entstehung der kalkoolithischen Fazies des norddeutschen Unteren Buntsandsteins. Beiträge zur Min. und Petr., 8 (3): 141-179.

CONSTITUTION AND BY-LAWS OF THE ILLINOIS STATE ACADEMY OF SCIENCE

(As of April 27, 1962)

CONSTITUTION

Article I. Name

This Society shall be known as the Illinois State Academy of Science.

Article II. Objects

1. The objects of the Academy shall be the promotion of scientific research, the diffusion of scientific knowledge and scientific spirit, and the unification of the science interests of the state.

Article III. Membership and Dues

1. Any person of good character, proposed by two members of the Academy, and recommended by the chairman of the Membership Committee may be elected to any class of membership in the Academy by a majority vote of the Council upon payment of scheduled dues. Any organization approved by the Chairman of the Sustaining Membership Committee may become a sustaining member or a patron upon payment of appropriate dues. Individuals who attended the organization meeting of the Academy in 1908, paid dues for that year, and signed the original constitution of the Academy are designated *charter members*.

2. Regular individual members in good standing shall have the privilege of voting at the annual meeting, holding office, offering papers for presentation at meetings subject to the approval of the appropriate Section Chairman and with right of appeal to the Council, having papers published in the TRANSACTIONS if accepted by the Board of Editors, and receiving one copy of the current TRANSACTIONS of the Academy. No member in arrears shall receive the TRANSACTIONS for any year for which he is or remains in arrears.

3. Any college or high school student who has not received a bachelor's degree and who is certified as such by an advisor or instructor may become a Student Member with all rights and privileges of membership except that of voting and holding office.

4. The dues shall be as follows:

Regular member, annual	$ 5.00
Student member, annual.	2.00
Life member, single payment	100.00
Sustaining member, annual	10.00-$49.00
Patron member, annual	50.00-more.

5. Proceeds from life memberships shall constitute an inviolate permanent investment fund from which only the annual income may be used. Proceeds from sustaining and patron memberships shall be used to finance the activities of the Junior Academy and to advance its program as shall be determined by the Council.

6. The fiscal year of the Academy shall be from January 1 through December 31. Members who fail to pay dues for any fiscal year shall be considered in arrears for that year, and unless they pay dues by the succeeding December 31 they shall be dropped from membership as of that date.

Article IV. Officers

1. A President, a First Vice-President, a Secretary, and a Treasurer shall be elected by the members of the Academy at its annual meeting, shall hold office for one year or until their successors are elected and take office, and shall perform the duties usually pertaining to their respective offices. The First Vice-President shall also assist the Secretary in formulating the program for the annual meeting.

2. If between annual meetings of the Academy the offices of both President and First-Vice-President shall become vacant, the last available Past President shall act as President until the next annual meeting. Interim vacancies in the offices of Secretary and Treasurer shall be filled by pro-tem officers elected by the Council.

3. A Second Vice-President, who shall preferably be a resident of the community in which the next annual meeting is to be held, shall be elected by the Council each year and shall serve as Chairman of Local Arrangements for that meeting. When possible, a Second Vice-

President Elect, who shall preferably be a resident of the community in which the second next annual meeting is to be held, shall also be elected by the Council, subject to confirming election as Second Vice-President by the next succeeding Council.

4. The Director (or Acting Director) of the State Museum Division of the Department of Registration and Education of the State of Illinois, or a member of the State Museum Staff designated by the Director to represent him on occasion of his temporary absence, shall be the Librarian of the Academy and as such shall have charge of all books, collections, and similar property of the Academy, shall serve as archivist of all official records and documents of the Academy, and shall have charge of the distribution, sale and exchange of publications of the Academy, in accordance with policies determined by the Council.

Article V. Council

1. The Council shall consist of the President, First Vice-President, Second Vice-President, Secretary, Treasurer, Librarian, General Chairman of the Junior Academy, the immediate Past President, the immediate Past Secretary, the immediate Past Treasurer, each for a term of one year, and four Councilors-at-large. These last shall be elected for four-year terms, only one being elected each year, except that the first year this provision is put into effect the terms of the three incumbent Councilors-at-large shall each be extended one year and a fourth Councilor-at-large shall be elected for a four-year term.

2. Except as otherwise herein provided, the members of the Council shall be elected annually by the members of the Academy at its annual meeting and interim vacancies in these positions shall be filled by pro-tem elections by the Council.

3. The Council shall manage the affairs of the Academy between annual meetings of the Academy and shall be responsible for the general planning, policies, program, and arrangements for annual meetings. It shall meet on call by the President ordinarily four times each year — once as soon as convenient after the annual meeting of the Academy, once each normally in November and February, and once just prior to the next annual meeting of the Academy.

Article VI. Technical Personnel

1. A Publicity Adviser shall be elected each year by the Council and he shall be responsible for appropriate publicity concerning all meetings and affairs of the Academy.

Article VII. Meetings of the Academy

1. The regular annual meeting of the Academy shall be held at such time and place as the Council may designate. Meeting places shall be determined at least two years in advance.

2. Special meetings of the Academy shall be called by the President upon written request by twenty members.

3. No meeting of the Academy shall be held without 30 days previous written notice by the Secretary to all members.

Article VIII. Junior Academy

1. In order to foster science among youth, the Academy is committed to sponsorship of an organization of junior high-school and high-school students interested in science and directed by qualified teachers in the schools of Illinois, which organization is termed the Junior Academy.

2. The affairs of the Junior Academy shall be conducted in accordance with policies and principles determined by the Council of the Academy.

3. The directing head of the Junior Academy shall be a General Chairman who shall be elected by the members of the Academy at its annual meeting. A General Chairman Elect shall also be so elected. If between annual meetings the position of General Chairman becomes vacant, the General Chairman Elect shall assume the position, and in this event or if for any other reason the position of General Chairman Elect becomes vacant, it shall be filled by pro-tem election by the Council.

4. No expenditures may be made and no bills or other liabilities may be incurred on behalf of the Junior Academy without prior approval of the Council.

Article IX. Publications

1. The regular publication of the Academy shall be the *Transactions of the Illinois State Academy of Science.*

2. Other publications may be authorized by the Council.

3. Papers presented at annual meetings of the Academy by non-members at the invitation or with the approval of the Council shall be eligible also for publication by the Academy.

Article X. Business and Finance

1. Life membership payments shall constitute an inviolate endowment fund which shall be invested in guaranteed securities and of which only the income, in lieu of annual dues of the life members, shall be used by the Academy.

2. A second investment fund consisting of donations, bequests not otherwise restricted, allotments transferred by the Council from surplus reserve in the treasury, and similar sources shall be maintained as an emergency reserve, and only the income from this fund shall normally be available for the expenses of the Academy.

3. No expenditures may be made and no bills or other liabilities may be incurred by any officer, individual, or committee on behalf of the Academy, unless they are included in the budget, without prior approval of the Council.

4. At its first meeting each Council shall approve a budget of expenditures that shall not exceed the total of the current balance and the anticipated receipts, which budget may be modified by the Council at its subsequent meetings. The Treasurer shall not make payments for approved expenditures in excess of the covering item in the approved budget without express approval of the President and the Secretary. Such excesses must be covered by modifications of the budget at the next Council meeting.

5. The Secretary and Editor shall each receive an honorarium in amounts to be determined by the Council. These honoraria shall be paid by the Treasurer annually in March.

6. The President, the Secretary, and the Treasurer shall be reimbursed for their expenses while attending Council meetings and annual meetings. Other members of the Council may be reimbursed for their expenses while attending Council meetings other than those held in connection with annual meetings.

Article XI. Affiliations

The Academy may enter into such relations or affiliation with other organizations of appropriate character as may be recommended by the Council and approved by the members of the Academy at its annual meeting.

Article XII. Amendments

Proposed amendments to this constitution shall become effective upon approval by three-fourths of the members present and voting at the annual business meeting of the Academy, provided that notice of the proposed changes has been sent by the Secretary to all members of the Academy at least twenty days before such meeting.

BY-LAWS OF THE ILLINOIS STATE ACADEMY OF SCIENCE

I. Order of Business

1. The business meetings of the Academy and the meetings of the Council shall be conducted in accordance with Robert's Rules of Order.

2. Fifteen members shall constitute a quorum of the Academy and six councillors shall constitute a quorum of the Council.

II. Committees and Delegates

1. The standing committees of the Academy shall be Affiliations, Animal Experimentation in Research, Budget, Conservation, Archaeological and Historical Sites, Legislation and Finance, Local Conventions, Membership, Research Grants, Science Talent, Sustaining Memberships, and Teacher Training. Any of these committees may be abolished and additional ones may be established upon recommendation of the Council at any annual meeting of the Academy.

2. The chairmen and members of the standing committees shall be elected by the members of the Academy at its annual meeting. Interim vacancies on the committees shall be filled by the Council, who shall have authority also to elect additional members.

3. The Local Conventions Committee shall consist of the last three available Second Vice-Presidents, the Secretary of the Academy *ex-officio*, and a representative of the Junior Academy.

4. There shall also be committees on Audit, Nominations, and Resolutions of which the members shall be appointed by the President not later than the February Council meeting.

5. The duties of the committees shall be as defined by the Council, except as hereafter provided.

6. The budget committee shall submit at the last Council meeting for its consideration and for review at the annual meeting of the Academy a budget of anticipated income and recommended expenditures for the following year. The

budget shall be approved by the succeeding Council at its first meeting.

7. The Local Conventions Committee shall prepare and maintain up-to-date a "hand book" for the guidance of Second Vice-Presidents in discharging their duties as Chairmen of Local Arrangements and shall further advise such officers when requested.

8. The membership of the Audit, Nominations, and Resolutions committees shall be announced to the members of the Academy by the President or the Secretary not less than 30 days prior to the annual meeting.

9. The Nominations Committee shall present at the annual business meeting of the Academy a list of candidates for all offices and committees which shall be filled by election by members of the Academy.

10. The Resolutions Committee shall present at the annual business meeting of the Academy all resolutions for consideration by the members of the Academy, with recommendations for or against approval. Members of the Academy who wish to sponsor resolutions shall submit them to the Resolutions Committee for consideration not less than 24 hours and preferably longer before the annual meeting. No resolution not submitted to the Committee may be presented at the meeting of the Academy. The Committee shall draft any appropriate resolutions as directed by the officers of the Academy or Council, may redraft any resolution submitted by any member or members to place it in more acceptable form, and may draft resolutions to incorporate suggestions offered by members of the Academy.

11. One or more delegates to the American Association for the Advancement of Science or to any other organization with which the Academy is affiliated, when such delegates are required, shall be elected by the Council for such a term or terms as the Council may designate.

III. Technical Sections

1. Technical papers presented at the annual meeting of the Academy will be distributed among Sections representing various fields of science as follows: Aquatic Biology; Anthropology; Botany; Chemistry; Geography; Geology; Meteorology and Climatology; Microbiology; Physics; Science Teaching; and Zoology.

2. Any of these sections may be abolished, divided, or combined by the Council as seems desirable, and other sections may be established by the Council upon request of ten active members.

3. Members of the Academy shall indicate in which section or sections they are particularly interested.

4. The members present at any section meeting during the annual meeting of the Academy shall constitute a quorum of the section. They shall elect a chairman for the ensuing year, who shall be responsible for assembling a program for the section for the next meeting. In the event that an elected chairman can not serve, a substitute shall be elected by the Council.

5. No paper shall be entitled to a place on the Section programs unless the manuscript or an abstract of the same shall have been previously delivered to the Secretary in accordance with instructions. No paper shall be presented at any Section meeting by any person other than the author, except with approval of a majority of the members present at such meeting. No paper shall be accepted for publication unless the author or a co-author is a member of the Academy or an approved applicant for membership or unless it has been presented at the invitation of or with the approval of the Council, nor shall any paper published wholly or in large part elsewhere be acceptable for publication.

IV. Publications

1. The publications of the Academy shall be under the supervision of a Committee on Publications, which shall consist of an Editor and a Board of Editors.

2. The Editor shall be appointed annually by the Council at its first meeting. He shall be chairman of the Committee on Publications and Technical Editor.

3. The Board of Editors shall consist of eight Associate Editors, of which one shall be for the Junior Academy, one shall be for News and Notes, and six shall represent various areas of science. The Associate Editors shall be appointed annually by the Council at its first meeting.

4. Sometime between May 1 and September 1 of even-numbered years the Editor and/or the members of the Board of

Editors shall confer with the Director of the Illinois State Museum concerning the amount of appropriations that should be requested for publication of the *Transactions* during the next State Biennium.

V. Suspension or Amendment of By-Laws

1. These by-laws may be suspended or amended at any annual meeting of the Academy by a majority vote of the members present.

PREPARATION OF MANUSCRIPTS FOR THE TRANSACTIONS

For publication in the *Transactions*, articles must present significant material that has not been published elsewhere. Review articles are excepted from this provision, as are brief quotations necessary to consider new material or varying concepts. All manuscripts must be typewritten, double spaced, with at least one-inch margins. The original copy, not the carbon copy, is to be submitted.

Titles should be brief and informative. The address or institutional connection of the author appears just below the author's name. Subtitles or center headings should be used; ordinarily one uses substitles such as *Introduction*, *Acknowledgments*, *Materials*, *Methods*, *Results*, *Discussion*, *Summary*, and *Literature Cited*. All papers should have a summary.

No footnotes are to be used.

The section entitled *Literature Cited* must include all references mentioned in text. It is not to include any other titles. No references to the literature are to be placed in footnotes. Citations under *Literature Cited* are as shown below:

Doe, John H. 1951. The life cycle of a land snail. Conchol., 26(3): 21-32, 2 tables, 3 figs.
Doe, John H. 1951. Mineralogy of Lower Tertiary deposits. New York, McGraw-Hill Book Co., iv + 396 pp.

Quoted passages, titles, and citations must be checked and rechecked for accuracy. Citations to particular pages in text are Doe (1908, p. 21) or (Doe, 1908, p. 21); general citation in text is Doe (1908) or (Doe, 1908).

Tabular information should be kept at a minimum. Tables should not be more than one page in length. Do not duplicate tabular data in text. Headings for tables and columns should be brief. Reduce to the barest essentials, or preferably omit, explanatory notes on tables. Each table and its heading should be on a single page; do not place any table on the same page with text.

Photographs should be hard, glossy prints of good contrast. Graphs, maps and other figures reproduce best when prepared for at least one-half reduction; lettering, numerals, etc. on all figures in a manuscript should, be worked out to proper size for such reduction. Line widths, letter size etc. should be uniform from figure to figure within a published paper. Figures should be drawn on good quality white paper or on drawing board. Use only India ink. Use a lettering device (Leroy or Wrico) for numerals and words; do not print "free-hand."

Legends for photographs and figures should be brief; type them on a separate sheet of paper. Indicate figure number and your name on back of illustration; do not write with pencil on the backs of photographs.

Authors will receive galley proofs; these should be read carefully and checked against the original manuscript. Reprints may be ordered at the time galley proofs are returned to the Editor.

Wesley J. Birge,
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ILLINOIS
Land of Lincoln