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EARLY PENNSYLVANIAN MICROFAUNAS OF THE ILLINOIS BASIN

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ABSTRACT.—Early Pennsylvanian fusulinids and ostracods of the Illinois Basin from Butler and Hancock Counties, Kentucky, and from many localities along the eastern margin of the Illinois Basin as far north as Warren County, Indiana, are discussed. Microfaunas include numerous species of ostracods, the fusulinids *Millerella*, *Paramillerella*, several species of *Profusulinella*, unnamed species of *Pseudostaffella*, specimens of questionable *Fusulinella*, and abundant speciments of *F. iowensis*. One new species of *Profusulinella* is described from Indiana. The lower Pennsylvanian strata are divisible into two ostracod biostratigraphic zones. The lower zone is characterized especially by *Amphissites rothi*, and three subzones are suggested. The upper biostratigraphic zone is characterized especially by *A. centronotus*. The ostracod fauna associated with *Fusulinella* from Desmoinesian rocks of the central part of the United States has been described previously.

Pennsylvanian rocks occur in the Illinois Basin over most of Illinois, a part of western and southwestern Indiana, and a large area in the north-central part of western Kentucky (Fig. 1). These rocks have been extensively studied by the Illinois, Indiana, and Kentucky Geological Surveys, and these state surveys have been the source of much of the information we have used to direct our study of the early Pennsylvanian microfaunas of the Illinois Basin in this region. It became evident to us during an early period of our study that the most primitive units available to surface observation and collecting are to be found in a belt extending from central Kentucky near Morgantown in Butler County along the eastern margin of the Pennsylvanian part of the Illinois Basin as far north as Warren County, Indiana (Fig. 2). Therefore, a progressive study of older to younger mircofaunas was conducted in this part of the Basin.

Our purpose is to review the status of knowledge on early Pennsylvanian fusulinids and ostracods of the Illinois Basin, and to make available our new information derived from extensive collections from lower Pennsylvanian rocks in Kentucky, Indiana, and Illinois (Table 1).

This paper is published with the permission of the Chief, Illinois State Geological Survey, and the State Geologist, Indiana Department of Conservation, Geological Survey.

INFORMATION DERIVED FROM FUSULINIDS

Dunbar and Henbest published a report in 1942 concerning all of the fusulinids known to them at that time from rocks of the Pennsylvanian System of Illinois. Their collections included extensive fusulinid faunas from the part of the Illinois section correlated with the Desmoinesian Series, as well as collections from the stratigraphically higher Livingston, Omega, Shumway, and Greenup Limestones of central Illinois. The collections from these four limestones contain species of *Triti-*

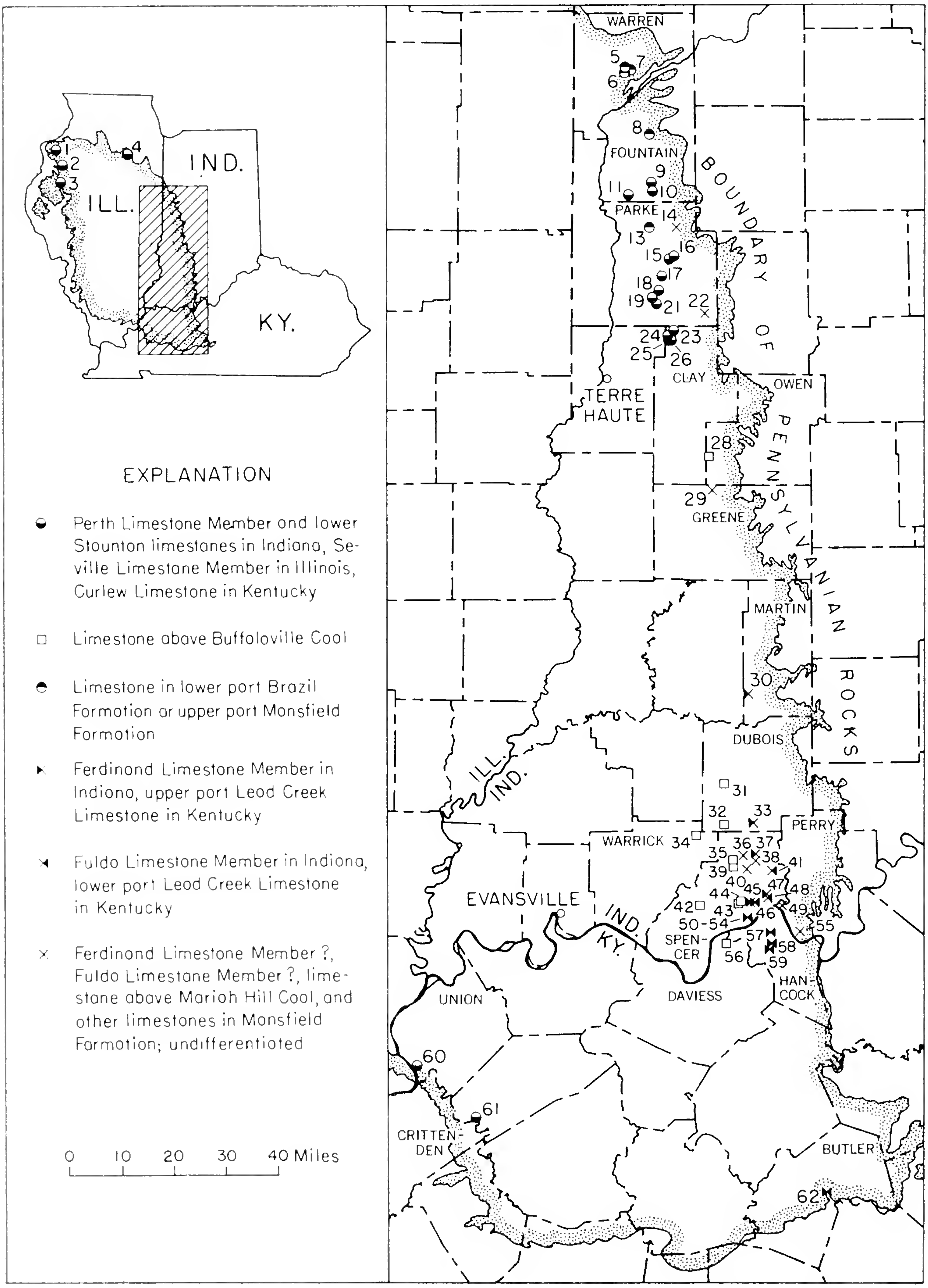


FIGURE 1.—Map of the southeastern part of the Illinois Basin showing collecting localities for lower Pennsylvanian microfaunas.

cites that indicate a late Pennsylvanian age. The fusulinid fauna, including such species as *T. callosus* Dunbar and Henbest from the Greenup Limestone in Cumberland County, is one of the most advanced to have been described from Illinois. The most primitive fusulinids described by Dunbar and Henbest from Illinois include the widely distributed *Fusulinella iowensis.* This was from the limestone caprock of the Rock Island (No. 1) Coal (Fig. 1, locs. 1, 2, and 3).

Collections of limestone containing a typical fauna of *Fusulinella stouti* were sent to Thompson by Erik N. K.-Waering in the 1930s from Crittenden County, Kentucky (loc. 61). These samples had been collected by D. W. St. Clair for the Shell Oil Company and were established by Shell geologists to be near 400 feet above the pre-Pennsylvanian surface. *F. stouti* was originally described by Thompson (1936) from rocks of the Pottsville Series of Ohio, and later was reported by Dunbar and Henbest (1942) from the limestone that forms the caprock over the Rock Island (No. 1) Coal in Illinois. The occurrence of *F. stouti* in Crittenden County, Kentucky, served to demonstrate that at least more than 400 feet of Pennsylvanian rocks are found in this area below the Curlew Limestone (Thompson, Shaver, and Riggs, 1959). This occurrence also encouraged Thompson to send students from the University of Wisconsin into Kentucky in search of fusulinid faunas representing the Zone of *Fusulinella,* the Zone of *Profusulinella,* and the Zone of *Millerella.*

The first pre-Desmoinesian microfaunas studied by us (Thompson, Shaver, and Riggs, 1959) from the Illinois Basin were obtained from central Kentucky on the southeast edge of the outcrop belt of Pennsylvanian rocks. These rocks occur as two thin limestones and associated shales exposed just north of Green River on the west side of U. S. Highway 231 in Butler County, about 760 feet above the pre-Pennsylvanian surface at locality 62. The fauna described from this area includes *Profusulinella kentuckyensis* Thompson and Riggs, *Millerella* spp., and *Paramillerella* spp. Cooper (1946) had previously described ostracod species of approximately similar ages from Spencer County, Indiana, including the diagnostic early Pennsylvanian species *Amphissites rothi* Bradfield and *Aurikirkbya triseriata* Shaver (= *Kirkbya kellettae* Cooper).

Hancock and Daviess Counties, Kentucky.—An examination of the limestone, and the fossiliferous shales and limestones 13 to 25 feet below this limestone, in Hancock County, Kentucky (locs. 57, 58, and 59) demonstrated the presence of numerous minute discoidal fusulinids of the genera *Paramillerella* and *Millerella.* Common to abundant specimens of elongate fusulinids also occur in these shales and limestones that seem identical in all measurable and observable features to *Profusulinella kentuckyensis* previously described from Butler County, Kentucky. These stratigraphic units are the rocks to which Crider (1913, p. 279) applied the name Lead Creek Limestone. Two characteristic exposures of this stratigraphic unit are found in county roadcuts that are about 1.0 mile south of Hilldale Church

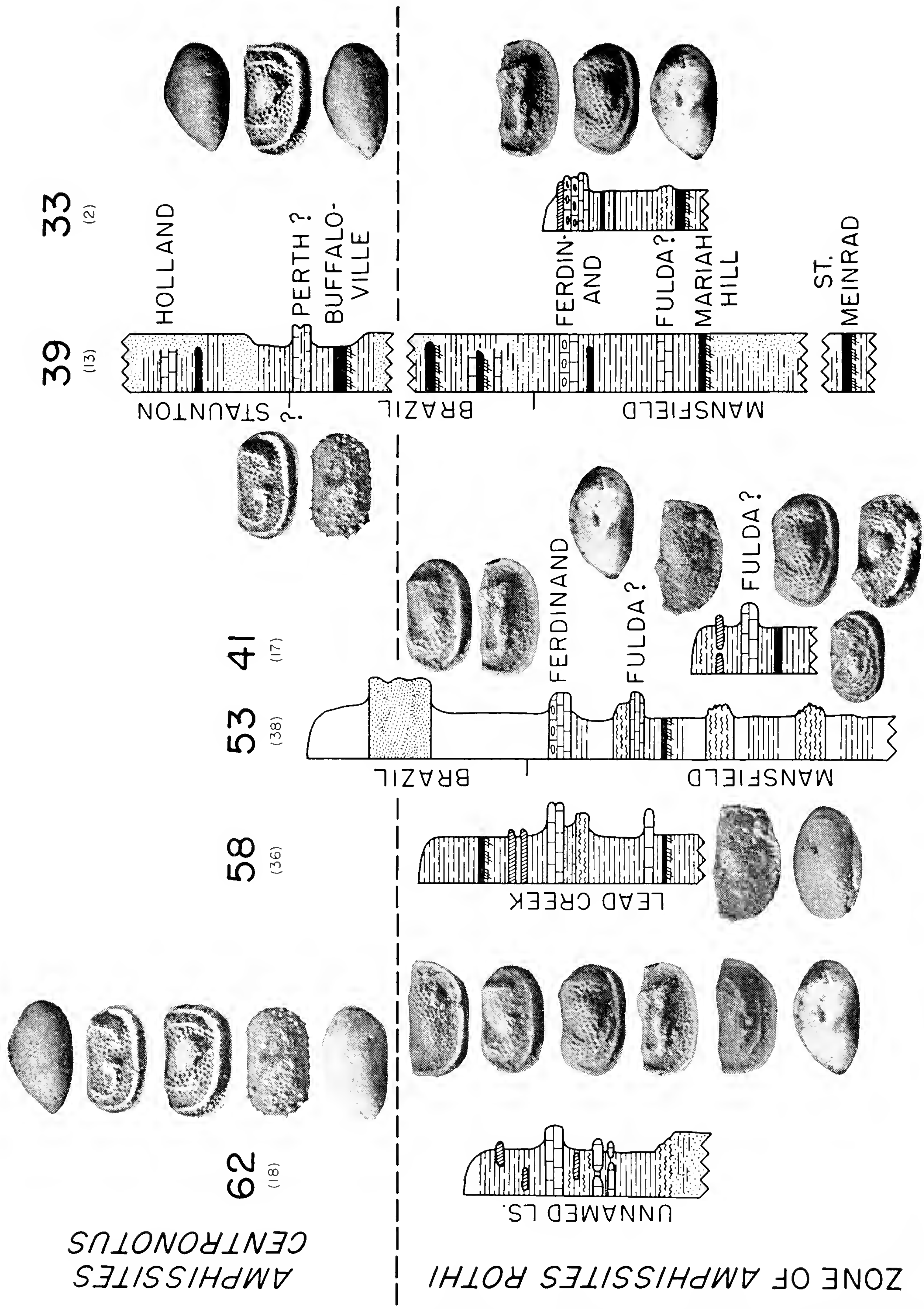
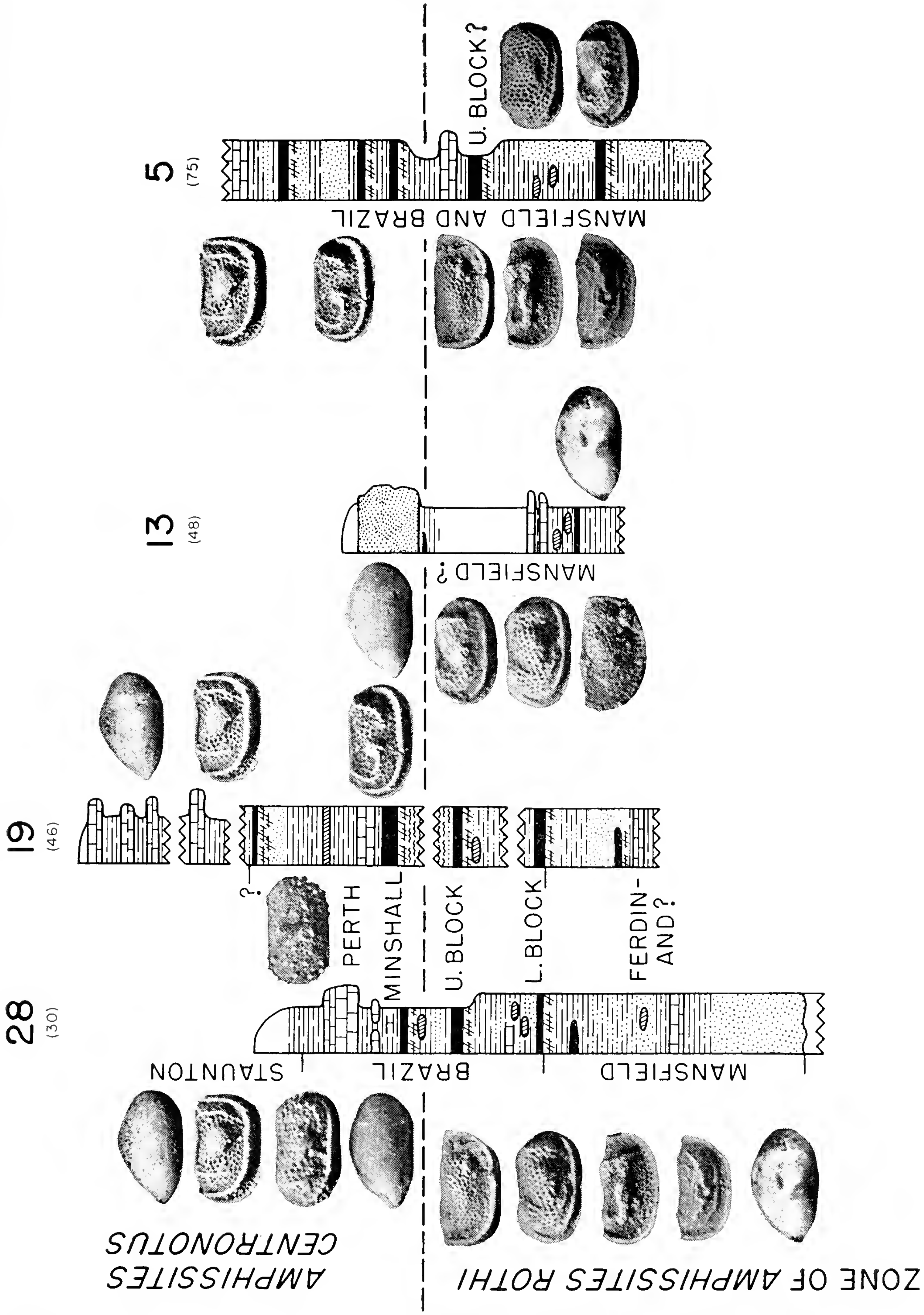


FIGURE 2.—Selected lower Pennsylvanian sections in Indiana and Kentucky. Some sections generalized from Hutchison (1956, 1959, 1961). See Figure 1 for locations of sections; numbers in parentheses are Shaver's field numbers. Illustrated ostracord specimens: to right of section 62 (ascending), *Bairdia dornickhillensis* Harlton, *Kirkbya magna* Roth, *Aurikirkbya triseriata* Shaver, *Amphissites rothi* Bradfield, *A. marginiferus* Roth, *Kirkbya* cf. *K. inornata* Roth, *Bairdia dornickhillensis* Harlton, *Roundyella* cf. *R. simplicissima* (Knight), *Amphissites cen-*



tronotus (Ulrich and Bassler), *A. girtyi* Knight, and *Bairdia oklahomaensis* Harlton; below section 58 (ascending), *Cavellinella casei* Bradfield and *Kirkbya* sp. (= *K.* cf. *K. reflexa Cooper*); below section 41, *Amphissites weaveri* Roth; to right of section 41, *Polytylites wapanuckaensis* (Harlton); to right of section 33, third specimen from top, *Bairdia dornickhillensis* Harlton; to left of section 28, third specimen from top, *Amphissites harlonti* (Cooper); and to right of section 5, at top: *Amphissites rothi* Bradfield. All other figures are duplicates.

TABLE 1.—List of Localities and Stratigraphic Positions Collectively for lower Pennsylvanian Fusulinid and Ostracod Collections of the Illinois Basin.

No.	Sample No. M.L.T.	Sample No. R.H.S.	Location	Stratigraphic Position
1	G3		Mercer Co., Ill. (see Dunbar and Henbest, 1942)	Spoon Formation, Seville Limestone Member
2	580		Warren Co., Ill. (see Dunbar and Henbest, 1942)	Spoon Formation, Seville Limestone Member
3	G7		Fulton Co., Ill. (see Dunbar and Henbest, 1942)	Spoon Formation, Seville Limestone Member
4	2219	108½	Island in Des Plaines River in the NW¼ sec. 29, T. 34 N., R. 9 E., south of Channahon, Will Co., Ill. (collected by J. M. Weller or H. E. Culver, 1932)	Limestone in lower part local Pennsylvanian section (Seville?)
5	Ind-28	75	Tributary to Pine Creek in the SW¼ SE¼sec. 16, T. 22 N., R. 8 W., at abandoned Burr Mine, Warren Co., Ind.	Limestone in lower part Brazil Formation or upper part Mansfield Formation
6		109	Ravine in the north center NE¼ sec. 21, T. 22 N., R. 8 W., 250 yards south of county road, Warren Co., Ind.	Limestone in lower part Brazil Formation or upper part Mansfield Formation
7		74	Tributary to Pine Creek in the NE¼ sec. 22, T. 22 N., R. 8 W., 200 yards below junction of Fall Creek, Warren Co., Ind.	Limestone in lower part Brazil Formation or upper part Mansfield Formation
8	Ind-108	108	Hytex Brick Co. clay pit in the NW¼ sec. 31, T. 20 N., R. 7 W., 2.0 miles north of Veedersburg, Fountain Co., Ind.	Limestone in lower part Brazil Formation or upper part Mansfield Formation
9	Ind-112	112	Tailings from abandoned coal mine in the SW¼ sec. 7, T. 18 N., R. 7 W., at Yeddo, Fountain Co., Ind.	Limestone in lower part Staunton Formation or upper part Brazil Formation
10	Ind-33	70	Morgan Coal Co. pit in the SW¼ sec. 20, T. 18 N., R. 7 W., 0.25 mile east of U. S. Highway 41, Fountain Co., Ind.	Limestone in lower part Staunton Formation or upper part Brazil Formation
11	Ind-51	50	Bank of Mill Creek in the NE¼ SE¼ NE¼ sec. 28, T. 18 N., R. 8 W., north of iron bridge, Fountain Co., Ind.	Limestone in lower part Staunton Formation or upper part Brazil Formation
13	Ind-60	48	South bank of Square Rock Branch in the NW¼ NW¼ NW¼ sec. 31, T. 17 N., R. 7 W., 0.25 mile southwest of Port-O-Woods landing field and 200 yards west of bridge, Parke Co., Ind.	Limestone in upper part Mansfield Formation or lower part Brazil Formation

14		69	Wapalo Creek bank in the center of east line NE¼ NW¼ sec. 36, T. 17 N., R. 7 W., west of iron bridge, Parke Co., Ind.	Limestone in Mansfield Formation
15	Ind-67	67	Sand Creek bank in the SE¼ SE¼ SE¼ sec. 33, T. 16 N., R. 7 W., at bridge on county road, Parke Co., Ind.	Brazil Formation, Perth Limestone Member
16	Ind-31	68	East valley wall in the SW¼ NW¼ sec. 34, T. 16 N., R. 7 W., about 35 feet above stream and along woods road at about 645 ft. altitude, Parke Co., Ind.	Brazil Formation, Perth Limestone Member
17	Ind-30		Stream valley in the west center of the NE¼ SE¼ sec. 17, T. 15 N., R. 7 W., Parke Co., Ind.	Limestone in upper part Brazil Formation or lower part Staunton Formation
18	Ind-55	47	Gully in the NE¼ SW¼ SE¼ sec. 5, T. 14 N., R. 7 W., 1.5 miles northeast of Minshall, Parke Co., Ind.	Limestone in upper part Brazil Formation or lower part Staunton Formation
19		46-3	Ravine in the SE¼ SE¼ sec. 7, T. 14 N., R. 7 W., across a divide from and west of iron bridge and county road, near Minshall, Parke Co., Ind.	Limestone in lower part Staunton Formation
21	Ind-26	46-0	Stream bed in the SE¼ sec. 7, T. 14 N., R. 7 W., west of road and just north of southernmost of two bridges at Minshall, Parke Co., Ind.	Limestone in upper part Brazil Formation or lower part Staunton Formation
22		65	Stream bank in east part of south line SE¼ sec. 22, T. 14 N., R. 6 W., Parke Co., Ind.	Limestone in Mansfield Formation
23	Ind-34	45	Abandoned coal pit in the south center of the SW¼ NE¼ sec. 3, T. 13 N., R. 7 W., 0.5 mile northwest of Perth, Clay Co., Ind.	Brazil Formation, Perth Limestone Member (type section)
24	Ind-116	116	Abandoned coal mine slope in the SE¼ NW¼ SW¼ sec. 3, T. 13 N., R. 7 W., in valley bottom, Clay Co., Ind.	Brazil Formation, Perth Limestone Member
25	Ind-117	117	Abandoned quarry in the SW¼ SW¼ SW¼ sec. 10, T. 13 N., R. 7 W., south of Little Creek, Clay Co., Ind.	Brazil Formation, Perth Limestone Member
26	Ind-115	115	Abandoned quarry in the NE¼ NW¼ NW¼ sec. 10, T. 13 N., R. 7 W., near New York Central Railroad overpass, Clay Co., Ind.	Brazil Formation, Perth Limestone Member
28	Ind-18	30	Abandoned coal pit in the SW¼ SW¼ sec. 2, T. 9 N., R. 6 W., 1.0 mile north of Coal City, Owen Co., Ind.	Limestone in Brazil Formation (Perth Limestone Member?)
29	Ind-98	98	Gully in the NW¼ SE¼ SE¼ sec. 6, T. 8 N., R. 5 W., in pasture northeast of farm house at about 570 ft. altitude, Greene Co., Ind.	Mansfield Formation, limestone below Lower Block Coal (Ferdinand Limestone Member?)
30		122	P. & R. Coal Co. coal pit in the SW¼ SW¼ SW¼ sec. 24, T. 2 N., R. 5 W., Martin Co., Ind.	Limestone in Mansfield Formation (Ferdinand Limestone Member?)

Table 1. — Continued

No.	Sample No. M.L.T.	Sample No. R.H.S.	Location	Stratigraphic Position
31	Ind-7	24	Roadcut in the east center NW¼ sec. 18, T. 2 S., R. 5 W., an eighth mile south of Patoka River, Dubois Co., Ind.	Limestone in upper part Brazil Formation or lower part Staunton Formation (limestone above Buffaloville Coal?)
32		77	Abandoned coal pit in the SE¼ SE¼ SE¼ sec. 31, T. 3 S., R. 5 W., north of county road, Dubois Co., Ind.	Brazil Formation, limestone above Buffaloville Coal
33	Ind-23	2	Roadcut in the NW¼ NW¼ sec. 29, T. 3 S., R. 4 W., 1.0 mile northwest of Ferdinand, Dubois Co., Ind.	Mansfield Formation, Ferdinand Limestone Member (type area)
34		124	Indiana Geol. Survey drill hole 43 in the SE¼ NE¼ SW¼ sec. 5, T. 4 S., R. 6 W., Underhill farm, 170.6 to 175.3 ft., Warrick Co., Ind.	Brazil Formation, limestone above Buffaloville Coal
35	Ind-13	125	Roadcut in the southeast corner of the SW¼ sec. 33, T. 4 S., R. 5 W., north side of road and 1.5 miles east of Lincoln City, Spencer Co., Ind.	Brazil Formation, limestone above Buffaloville Coal
36	Ind-37	85	Abandoned coal pit in the SW¼ sec. 26, T. 4 S., R. 5 W., east of blacktop road, Spencer Co., Ind.	Mansfield Formation, limestone above Mariah Hill Coal (type area) (Fulda Limestone Member?)
37	Ind-43	87	Ind. Highway 162 cut in the NE¼ NW¼ NW¼ sec. 20, T. 4 S., R. 4 W., Spencer Co., Ind.	Limestone in upper part Mansfield Formation or lower part Brazil Formation (Ferdinand Limestone Member?)
38	Ind-42	86	Roadcut in the SW¼ NW¼ NW¼ sec. 25, T. 4 S., R. 5 W., Spencer Co., Ind.	Mansfield Formation, limestone above Mariah Hill Coal (Fulda Limestone Member?)
39	Ind-32	13	Abandoned coal pit in the NE¼ NW¼ sec. 9, T. 5 S., R. 5 W., Spencer Co., Ind.	Brazil Formation, limestone above Buffaloville Coal (type area)
40	Ind-49	104	Abandoned coal pit in the NW¼ SE¼ sec. 12, T. 5 S., R. 5 W., Spencer Co., Ind.	Mansfield Formation, limestone above Mariah Hill Coal (Fulda Limestone Member?)
41		17	Ind. Highway 545 cut in the SW¼ NE¼ SW¼ sec. 11, T. 5 S., R. 4 W., 1.5 miles south of Fulda, Spencer Co., Ind.	Limestone in Mansfield Formation (Fulda Limestone Member?)
42		123	Indiana Geol. Survey drill hole 42 in the SE¼ SE¼ NW¼ sec. 16, T. 6 S., R. 6 W., Trinkel farm, 385.0 to 385.8 ft., Spencer Co., Ind.	Brazil Formation, limestone above Buffaloville Coal

43	Ind-8	11	Ind. Highway 70 cut in the SE¼ SW¼ sec. 10, T. 6 S., R. 5 W., 0.5 mile west of Newtonville, Spencer Co., Ind.	Brazil Formation, limestone above Buffaloville Coal
44	Ind-44	89	County roadcut in the SW¼ SW¼ SE¼ sec. 10, T. 6 S., R. 5 W., an eighth mile north of Ind. Highway 70, Spencer Co., Ind.	Brazil Formation, limestone above Buffaloville Coal
45	Ind-12	12	Ind. Highway 70 cut on the south line of the SW¼ SE¼ sec. 7, T. 6 S., R. 4 W., 2.75 miles east of Newtonville, Spencer Co., Ind.	Limestone in Mansfield Formation (Ferdinand Limestone Member?)
46	Ind-15	16	Abandoned clay pit in the SW¼ SW¼ NW¼ sec. 9, T. 6 S., R. 4 W., east of county road, Spencer Co., Ind.	Limestones in Mansfield Formation (Fulda and Ferdinand Limestone Members?)
47	Ind-105	105	Roadcut at the center of the south line SW¼ sec. 34, T. 5 S., R. 4 W., 0.5 mile south of Evanston, Spencer Co., Ind.	Limestone in Mansfield Formation (Ferdinand Limestone Member?)
48		107	County roadcut in the west center SE¼ SW¼ sec. 2, T. 6 S., R. 4 W., near Maxville, Spencer Co., Ind.	Limestone in Mansfield Formation (Fulda Limestone Member?)
49	Ind-61	4	Ind. Highway 66 cut in the NE¼ SE¼ sec. 13, T. 6 S., R. 4 W., near top of cut, east of Troy, Perry Co., Ind.	Calcareous sandstone in Mansfield Formation
50	Ind-54	90	Quarry in the SE¼ SW¼ SW¼ sec. 25, T. 6 S., R. 5 W., north of Ind. Highway 66, Spencer Co., Ind.	Limestones in Mansfield Formation (Fulda and Ferdinand Limestone Members?)
51	Ind-9	7	Abandoned sandstone quarry in the west center of the NE¼ sec. 35, T. 6 S., R. 5 W., north side of Ind. Highway 66, Spencer Co., Ind.	Limestone in Mansfield Formation (Ferdinand Limestone Member?)
52	Ind-3	8	Bluff above Ind. Highway 66 in center of the NE¼ NE¼ sec. 35, T. 6 S., R. 5 W., Spencer Co., Ind.	Limestone in Mansfield Formation (Ferdinand Limestone Member?)
53	Ind-20	38	Bluff above Ind. Highway 66 in the SE¼ SW¼ NW¼ sec. 20, T. 6 S., R. 4 W., southwest of county road north of highway, Spencer Co., Ind.	Limestones in Mansfield Formation (Fulda and Ferdinand Limestone Members?)
54	Ind-1,2	10	County roadcut in the west center of the NE¼ NW¼ sec. 20, T. 6 S., R. 4 W., 0.25 mile northwest of Ind. Highway 66, Spencer Co., Ind.	Limestones in Mansfield Formation (Fulda and Ferdinand Limestone Members?)
55		35	Ind. Highway 237 cut in the NW¼ sec. 3, T. 7 S., R. 3 W., 2.0 miles north of Cannelton, Perry Co., Ind.	Limestone in Mansfield Formation
56	Ky-11	39	Alcove above abandoned mine drift, south side of Blackford Creek, 100 yards west of Louisville and Nashville Railroad trestle, 4.5 miles southwest of Lewisport, Daviess Co., Ky.	Lower Pennsylvanian limestone (higher than Lead Creek Limestone)

Table 1. — Continued

No.	Sample No. M.L.T.	Sample No. R.H.S.	Location	Stratigraphic Position
57	Ky-12	40	Coal pit 0.2 mile south of U. S. Highway 60, 0.7 mile west of crossroads with BM 506, 4.5 miles west of Hawesville, Hancock Co., Ky.	Upper and lower parts of Lead Creek Limestone
58	Ky-8,9	36	Both sides of county roadcut just south of junction with BM 435, 1.0 mile south of Hilldale Church, 4.0 miles west of Hawesville, at 474 to 503 ft. altitude, Hancock Co., Ky.	Upper and lower parts of Lead Creek Limestone
59	Ky-10	37	Both sides of county roadcut about 1.0 mile south of BM 435, south side of stream valley, 2.0 miles south of Hilldale Church, 4.5 miles west of Hawesville, 448 to 479 ft. altitude, Hancock Co., Ky.	Upper and lower parts of Lead Creek Limestone
60	Ky-4	21	Ravine southwest side of Indian Hill, 1.0 mile south of Curlew, Union Co., Ky.	Curlew Limestone
61	Ky-1		Kentucky Highway 120 cut, north side, 5.3 miles west of Providence in Crittenden Co., Ky.	Curlew Limestone
62	Ky-2,3	18	U. S. Highway 231 cut, north of Green River, 1.0 mile north of Morgantown, Butler Co., Ky.	Lower Pennsylvanian limestone (Lead Creek Limestone equivalent?)

TABLE 2.—Characteristic Species from Marine Zones of the lower Pennsylvanian Rocks of the Illinois Basin. The ostracod lists in part are collective for the zones.

Rock Unit and Area	Fusulinids	Ostracods
Perth Limestone Member of Brazil Formation; limestone in lower part Staunton Formation, west central Ind.; Seville Limestone Member of Spoon Formation, Mercer, Warren, Fulton, and Will Counties, Ill.; Curlew Limestone, western Ky.	*Fusulinella iowensis* Thompson *F. stouti* Thompson (Localities 1-3, 9-11, 15-18, 21, 23-26, 60, 61)	*Amphissites centronotus* (Ulrich and Bassler) *A. girtyi* Knight *A. harltoni* (Cooper) *Bairdia dornickhillensis* Harlton *Roundyella* cf. *R. simplicissima* (Knight) (Localities 4, 11, 19)
Limestone above Buffaloville Coal of Brazil Formation, Dubois, Spencer, and Warrick Counties, Ind; limestone in Brazil Formation near Coal City, Owen Co., Ind.; limestone on Blackford Creek, Daviess Co., Ky.	*Fusulinella?* (Localities 28, 31, 35, 39, 43, 44, 56)	*Amphissites centronotus* (Ulrich and Bassler) *A. girtyi* Knight *Bairdia dornickhillensis* Harlton *Roundyella* cf. *R. simplicissima* (Knight) (Localities 28, 32, 34, 39, 42)
Limestone in lower part Brazil Formation or upper part Mansfield Formation, near Pine Creek, Warren Co.; near Veedersburg, Fountain Co.; Square Rock Branch, Parke Co.; all Ind.	*Profusulinella burrensis*, n. sp. *Pseudostaffella* sp. *Millerella* spp. *Paramillerella* spp. (Localities 5, 8, 13)	*Amphissites marginifierus* Roth *A. rothi* Bradfield *Aurikirkbya triseriata* Shaver *Bairdia dornickhillensis* Harlton *Kirkbya magna* Roth *K.* cf. *K. inornata* Roth (Localities 5-8, 13)
Limestone below Lower Block Coal (Ferdinand Limestone Member?), Greene Co.; Ferdinand Limestone Member?, Martin Co.; both Ind.	*Millerella* (Locality 29)	*Amphissites rothi* Bradfield (Locality 30)
Upper part Lead Creek Limestone, Hancock Co., Ky.; Ferdinand Limestone Member, Spencer and Dubois Counties, Ind.	*Profusulinella kentuckyensis* Thompson and Riggs *Pseudostaffella* sp. *Millerella* spp. *Paramillerella* spp. (Localities 33, 37, 45-47, 50-54, 57-59)	*Amphissites marginiferus* Roth *A. rothi* Bradfield *Aurikirkbya triseriata* Shaver *Bairdia dornickhillensis* Harlton (Localities 33, 46, 50, 53, 54, 58)
Lower part Lead Creek Limestone, Hancock Co., Ky.; Fulda Limestone Member?, Spencer Co., Ind.	*Profusulinella kentuckyensis* Thompson and Riggs *Millerella* spp. *Paramillerella* spp. (Localities 46, 54, 57, 58)	*Amphissites marginiferus* Roth *A. rothi* Bradfield *Aurikirkbya triseriata* Shaver *Bairdia dornickhillensis* Harlton *Kirkbya magna* Roth *K.* cf. *K. inornata* Roth *K.* sp. (= *K.* cf. *K. reflexa* Cooper) (Localities 46, 48, 54, 57-59)

TABLE 2. — Continued

Rock Unit and Area	Fusulinids	Ostracods
Limestone above Mariah Hill Coal of Mansfield Formation, Spencer Co., Ind.	*Profusulinella kentuckyensis* Thompson and Riggs *Millerella* spp. *Paramillerella* spp. (Localities 36, 38, 40)	
Lower Pennsylvanian limestone at Morgantown, Butler Co., Ky.	*Profusulinella kentuckyensis* Thompson and Riggs *Millerella* spp. *Paramillerella* spp. (Locality 62)	*Amphissites rothi* Bradfield *Aurikirkbya triseriata* Shaver *Bairdia dornickhillensis* Harlton *B.* cf. *B. ardmorensis* Harlton (Locality 62)
Fulda Limestone Member? south of Fulda, Spencer Co., Ind.		*Amphissites marginiferus* Roth *A. rothi* Bradfield *A. weaveri* Roth *Aurikirkbya triseriata* Shaver *Kirkbya* sp. (= *K.* cf. *K. reflexa* Cooper) *Polytylites wapanuckaensis* (Harlton) (Locality 41)
Limestone in Mansfield Formation, eastern Parke Co., Ind.		*Amphissites marginiferus* Roth *A. rothi* Bradfield *Kirkbya* sp. (= *K.* cf. *K. reflexa* Cooper) (Localities 14, 22)
Limestone in Mansfield Formation, near Cannelton and Troy, Perry Co., Ind.	*Profusulinella* sp. (Locality 49)	*Amphissites rothi* Bradfield *Aurikirkbya triseriata* Shaver *Bairdia dornickhillensis* Harlton *Cavellinella casei* Bradfield *Kirkbya* sp. (= *K.* cf. *K. reflexa* Cooper) (Localities 49 and 55)

and 4.0 miles west of Hawesville (loc. 58) and 2.0 miles south of Hilldale Church and 4.5 miles west of Hawesville (loc. 59). The Kentucky Geological Survey has determined, from the best well data available, that this limestone is about 270 feet above the pre-Pennsylvanian surface in this area.

A limestone that is exposed 100 yards west of the Louisville and Nashville Railroad trestle over Blackford Creek in Daviess County, Kentucky (loc. 56), contains numerous specimens of an undescribed species of *Fusulinella?*. Further studies of these specimens will be necessary before definite identifications or generic assignments can be made. The actual vertical distance of the limestone exposed at locality 56 above the Lead Creek Limestone has not been determined. No elements of the prolific faunas of *Millerella* and *Paramillerella* found in the Lead Creek Limestone near Hawesville, Kentucky, were recognized among our specimens from the limestone exposed in the bluffs of Blackford Creek. This limestone (loc. 56), described by Crider (1913, p. 278), is tentatively correlated by the Indiana geologists and us with the limestone that occurs over the Buffaloville Coal of the Brazil Formation (upper Pottsville) in Spencer County, Indiana. The Indiana geologists also have considered this limestone to be the approximate equivalent of the Perth Limestone Member of the Brazil Formation in Clay County and more northerly counties, Indiana; we obtained no information from the fusulinids that support this correlation.

The fusulinid *Fusulinella iowensis*, considered to be a younger form than *Profusulinella*, has not been recognized in our collections from Butler, Hancock, and Daviess Counties, Kentucky.

Spencer, Dubois, and Perry Counties, Indiana.—Several limestone exposures have been described and named from Spencer and Dubois Counties, Indiana, that seem similar in several respects to the Lead Creek Limestone west of Hawesville in Hancock County, Kentucky, and the limestone on Blackford Creek in Daviess County, Kentucky. One of the oldest stratigraphic marine units that we recognize in the Pennsylvanian of southern Indiana crops out at an altitude of 585 feet along Indiana Highway 237, about 2.0 miles north of Cannelton, Perry County, Indiana (loc. 55). The limestone here is coarsely crystalline and does not contain any fusulinids; it does contain elements of the early ostracod faunas described herein (Table 2). Another of the lower Pennsylvanian fossiliferous units is a calcareous sandstone or limestone conglomerate that crops out in the bluff along Indiana Highway 66, just east of Troy, Perry County (loc. 49). It contains weathered and possibily detrital specimens of *Profusulinella* and elements of the early ostracod faunas (Table 2).

Franklin (1944) proposed the name Ferdinand Limestone without giving a precise outcrop for its type section. The name is presumed to have been proposed in part for limestone exposed on the road about 1.0 mile northwest of the town of Ferdinand (loc. 33) and at several places to the northeast of Ferdinand in southern Dubois County (T. 3 S., R. 4 W.). The Ferdinand is here considered to have member status in the Mansfield Formation.

The name Fulda Limestone was published by Franklin (1944), and exposures presumably of one limestone bed, south of Fulda on the road to New Boston, were intended to be the type section.

The stated location of Franklin's section illustrating the Fulda Limestone and Ferdinand Limestone relationships is not in the Fulda Limestone type area. Thus we are uncertain of the stratigraphic relationships of the one remaining good exposure south of Fulda (Table 1, loc. 41) to the Ferdinand Limestone and to other exposures mentioned by Franklin. We provisionally use the name Fulda Limestone, however, which is here accorded member status in the Mansfield Formation, for the lower of two limestones that are seen in the upper part of the Mansfield Formation in many sections in Spencer County (Table 1).

No fusulinid has been found from the Fulda Limestone south of Fulda (loc. 41). At this locality, however, Shaver found numerous ostracods (Table 2) with Chesterian (late Mississippian) and early Pennsylvanian affinities. Probably Cooper's (1946) ostracod locality 1 is the same, although his location is stated differently.

Fusulinids referable to the genera *Profusulinella*, *Millerella*, and *Paramillerella* have been found in the Ferdinand Limestone exposed along the highway about 1.0 mile northwest of Ferdinand (loc. 33). These specimens of *Profusulinella* include many that seem identical to the type specimens of *Profusulinella kentuckyensis* from Morgantown, Kentucky. They are associated with abundant unnamed species of *Millerella* and *Paramillerella* similar to the group of specimens illustrated from Morgantown by Thompson and Riggs (*in* Thompson, Shaver, and Riggs, 1959). They are also associated with abundant specimens referable to *Pseudostaffella*.

The Ferdinand Limestone exposed northwest of Ferdinand is highly cherty and contains scattered chert masses throughout. Drill records from nearby wells show that this limestone lies about 270 feet above the pre-Pennsylvanian surface. Numerous exposures of cherty limestone, probably of the Ferdinand, are found on the bluffs of the Ohio River north of Indiana Highway 66 for several miles northeast of Grandview in Spencer County (locs. 50-54) and in a roadcut on Indiana Highway 70, 2.75 miles east of Newtonville (loc. 45). Two prominent fossiliferous intervals have been recognized in this area. The upper one is the highly cherty limestone that is composed almost entirely of chert at some places. In many places, locality 54 for example, it contained great numbers of *Profusulinella kentuckyensis* and numerous ozawainellid fusulinids. The lower fossiliferous zone, about 16 feet below the upper zone, contains limestone and highly calcareous shale, as shown at localities 46 and 54. Both the shale and the limestone have numerous specimens of *Profusulinella kentuckyensis* and ozawainellid types of fusulinids. The upper cherty limestone, and the fossiliferous shale 13 to 20 feet below, are well exposed at localities 50, 53, and 54, and especially in the abandoned clay pit at locality 46. Some of these limestone exposures were named the Grandview Limestone by Franklin (1944), which he considered to be above the Ferdinand Limestone; Hutchison (1959), however, considered that the two ledges are exact or approximate equivalents of the Fulda and Ferdinand Limestones, and that these beds lie below the position of the Buffaloville Coal.

A coal in the northwestern and central parts of Spencer County has an overlying caprock limestone that bears, informally, the name Buffaloville Limestone, the same local name as the coal. To the northeast of Lincoln State Park (loc. 35), on and near Indiana Highway 70 near Newtonville (locs. 43 and 44), and near Buffaloville in the northern part of Spencer County (loc. 39), a thick limestone has been recognized above the Buffaloville Coal that contains common specimens of *Fusulinella?* which resemble or are identical to the specimens that we obtained at the bluffs of Blackford Creek in Daviess County, Kentucky (loc. 56). A similar fauna was found in limestone near the Patoka River in Dubois County (loc. 31).

The limestone, possibly the Fulda Limestone, over the Mariah Hill Coal near the town of Mariah Hill in northern Spencer County, in the abandoned strip mines at localities 36 and 40, and in a county roadcut at locality 38, contains great numbers of *Profusulinella kentuckyensis* and abundant specimens of unnamed species of *Millerella* and *Paramillerella*. There are several structural disturbances between the Mariah Hill area and the Ohio River, including anticlines and synclines (Hutchison, 1959). As a result, we are uncertain of the stratigraphic relationships of the Fulda and Ferdinand Limestones on the Ohio River bluff (locs. 50-54) to the limestone over the Mariah Hill Coal, but their fusulinids are similar. Two probable Ferdinand Limestone exposures yielding *Profusulinella* in the area of the Mariah Hill Coal are found at localities 37 and 47. The probable Ferdinand Limestone has been recognized as far north as locality 29, southwest of the Eel River in northern Greene County, Indiana. Here the limestone lies below the Lower Block Coal and contains abundant specimens of *Millerella,* but no other types of fusulinids. This occurrence is interesting because it represents one of the more prolific faunas of *Millerella* observed from this part of Indiana.

Owen and Clay Counties, Indiana.—The broad alluviated valleys of the Patoka and White Rivers interrupted our systematic northward collecting from the lower part of the Pennsylvanian between southern Dubois County and Owen County, Indiana. The floodplain of the Eel River also restricts Pennsylvanian exposures in Clay and Owen Counties. Collections from the limestone at locality 28 yielded several specimens of fusulinids that resemble specimens of *Fusulinella?* collected from the limestone over the Buffaloville Coal in Spencer County, Indiana (loc. 35), and the limestone on Blackford Creek in Daviess County, Kentucky (loc. 56). The limestone near Coal City (loc. 28), formerly called the Minshall Limestone (Kottlowski, 1959), was traced northward through Clay County (Hutchison, 1956). Hutchison (1960) correlated this limestone with the Perth Limestone

Member of the Brazil Formation. The fusulinid evidence does not support this determination; the ostracod evidence does not oppose the correlation.

Parke, Fountain, and Warren Counties, Indiana.—The deeply intrenched valley and tributaries of Sugar Creek have exposed the caprock limestones, black shales, and thin coal beds just to the southwest of Port-O-Woods landing field in northern Parke County, Indiana (loc. 13). The limestone at this locality on the south side and in the bottom of Square Rock Branch has yielded fusulinid faunas of *Profusulinella, Millerella,* and *Pseudostaffella* (Pl. 1, figs. 8, 11, 13, 14) which indicate beds, generally considered to be a part of the Mansfield Formation or a lower part of the Brazil Formation, that are only slightly younger stratigraphically than the *Profusulinella* found in the Ferdinand Limestone of southern Indiana, the Lead Creek Limestone of northern Kentucky, and the limestones at Morgantown, Kentucky.

The Hytex Brick Company clay pit located about 2.0 miles north of Veedersburg in Fountain County (loc. 8) contains a discontinuous massive limestone that occurs about 80 feet above the pre-Pennsylvanian surface, as determined from data from nearby wells. This limestone contains a fauna of *Profusulinella burrensis,* n. sp. (Pl. 1, figs. 1-10), described below, undescribed species of *Millerella* (Pl. 1, figs. 12, 13), and scarce specimens of an undescribed form of *Pseudostaffella* (Pl. 1, fig. 14). The fusulinid faunas found in the limestone near Veedersburg seem to be identical to those that are found in the limestone at locality 5 in Warren County, discussed below.

Coals that are mined on or near Pine Creek of central Warren County have an overlying caprock that is only a few feet thick. The caprock is highly variable in thickness along its exposures and has very irregular top and bottom surfaces. Fossils are common throughout this limestone, and thin sections reveal an abundant fauna of *Profusulinella burrensis* and common specimens of *Millerella* sp. and *Paramillerella* sp. A number of exposures of the limestone have been observed among the tributaries of Pine Creek, but fusulinids have been found in only one of them at locality 5, which is known locally as Burr Mine. Although some Indiana and Illinois geologists, Hutchison (1961) for example, have considered these limestone exposures to be correlative with the Perth (Minshall of older reports), the microfaunas, both fusulinids and ostracods, suggest that they belong to a lower unit, possibly in the Brazil Formation.

Perth and lower Staunton limestones in Clay, Parke, and Fountain Counties, Indiana.—The name Perth Limestone Member, of the Brazil Formation, was proposed by Hutchison (1960, p. 20) for the limestone exposed in the strip mine excavations half a mile northwest of the town of Perth, Clay County, Indiana, located in the Brazil West Quadrangle (loc. 23). It replaces for the most part the name Minshall Limestone of older reports, which was applied to limestones in several stratigraphic positions. The type section lies about 340 feet above the pre-Pennsylvanian surface at this locality according to data from nearby deep wells.

The Perth Limestone is 6.3 feet thick at its type exposure (Hutchison, 1960). Its upper and lower surfaces are irregular to knobby, and it contains abundant chert masses. Limestones considered to be the time equivalent of the Perth Limestone were studied by us at numerous places between the type locality of the Perth Limestone in Clay County and the southern part of Fountain County at localities 9 and 10. Hutchison (1961) considered that some of these exposures in southern Fountain County belong in the Staunton Formation, but the fusulinids suggest that they correspond in age to the Perth Limestone. Fusulinids that are referable to the species *Fusulinella iowensis* are abundant throughout these limestone exposures. Specimens of *F. iowensis* are not associated with speciments of *Millerella* or *Paramillerella* at any of the numerous localities where *F. iowensis* has been studied by us.

Fusulinella iowensis is also found in closely associated limestones, assigned to the Staunton Formation by Indiana geologists, at localities 15, 16, 17, 18, and 21 in Parke County, locality 11 in Fountain County, and localities 24, 25, and 26 in Clay County. Thus the Perth Limestone or closely associated lower Staunton limestones, with an abundant fauna of *F. iowensis,* are found commonly between localities 9 in southern Fountain County and 25 in extreme northern Clay County. *F. iowensis* was also described by Thompson and Riggs (*in* Thompson, Shaver, and Riggs, 1959) from the Curlew Limestone on Indian Hill in Union County, Kentucky (loc. 60).

Information Derived From Ostracods

The ostracods that have been collected from a few score localities along the eastern margin of the Illinois Basin show that the lower part of the Pennsylvanian section can be assigned to two easily recognized biostratigraphic zones. Many of these ostracods are illustrated on the accompanying Figure 2 together with characteristic sections at the selected locations.

The lowest zone, an assemblage zone here named the Zone of *Amphissites rothi,* is characterized especially by *A. rothi* Bradfield and by *A. marginiferus* Roth, *A. weaveri* Roth, *Aurikirkbya triseriata* Shaver (= *Kirkbya kellettae* Cooper), *Bairdia dornickhillensis* Harlton, *Cavellinella casei* Bradfield, *Kirkbya magna* Roth, *K.* cf. *K. inornata* Roth, *K.* sp. (= *K.* cf. *K. reflexa* Cooper), and *Polytylites wapanuckaensis* (Harlton). This fauna, associated with *Profusulinella kentuckyensis* or *P. burrensis, Millerella* spp., and *Paramillerella* spp., comes *collectively* from shales associated with unnamed lower Pennsylvanian limestones at Morgantown in Butler County, Kentucky (loc. 62), the Lead Creek Limestone (Caseyville in age) in Hancock County, Kentucky (locs. 57, 58, and 59), and from limestones in the Mansfield Formation (lower Pottsville), which crop out in the area between the Ohio River and Parke County, Indiana, including Fulda and Ferdinand Limestones. Some exposures yielding this fauna are found in the Ohio River bluff northeast of Grandview, Spencer County (locs. 46, 48, 50, 53, and 54), in roadcuts in the bluff in southern Perry County (locs. 49 and 55), a roadcut 1.0 mile northwest of Ferdinand, Dubois County (loc. 33), in the P. & R. Coal Company mine in southwestern Martin County (loc. 30), on Square Rock Branch, and other small tributaries in Parke County (locs. 13, 14, and 22). Thus the Zone of *Amphissites rothi* embraces the sequence of lower Pennsylvanian rocks that contain the fossiliferous marine units next below the Buffaloville Coal and the Perth Limestone Member of the Brazil Formation. The *Amphissites rothi* fauna is also found in shale and limestone associated with what is here considered to be the Upper Block Coal of the Brazil Formation, or a lower coal near what has been called Burr Mine in Warren County, Indiana (locs. 5, 6, and 7) and in the shaly part of the limestone near the top of the Hytex Brick Company clay pit 2.0 miles north of Veedersburg, Fountain County (loc. 8). At the Warren County site both the rock sequence and the fauna, in which *Kirkbya* cf. *K. inornata,* a modified form of *Aurikirkbya triseriata,* is characteristic, suggest that a higher subzone (of the Zone of *Amphissites rothi*) would be a useful biostratigraphic unit. This fauna occurs with the new fusulinid species, *Profusulinella burrensis,* described below.

The early Pennsylvanian species *Amphissites weaveri* and *Polytylites wapanuckaensis,* both having Chesterian affinities, are found associated with *A. rothi* only in the rocks at locality 41, generally called the Fulda Limestone, in Spencer County, Indiana. In the absence of spindle-shaped fusulinids from this location, they may indicate a lower part of the Zone of *Amphissites rothi.*

In the absence of satisfactory knowledge of ostracods of Atokan age from the Midcontinent area, the *Amphissites rothi* fauna of this study can be compared closely only with faunas from Midcontinent rocks that have been considered to be Morrowan in age. These Midcontinent faunas are from the Jolliff and Otterville Limestones of the lower part of the Dornick Hills Group of southern Oklahoma, from the basal part of the Marble Falls Limestone of Texas, which has been called Morrowan in age, from the Johns Valley Shale of Oklahoma, and from the Wapanucka Limestone of Oklahoma. In eastern Ohio a comparable fauna comes from the Poverty Run Limestone that is above the Vandusen Coal in the Pottsville Series (Marple, 1952). Thus, although some students (Kosanke, Simon, Wanless, and Willman, 1960) have considered the rocks of this zone in Indiana to be Desmoinesian in age, the ostracods offer no supporting evidence.

The zone containing the *Amphissites rothi* fauna is overlain in sharp faunal contrast by a zone, not named formally here because of its indeterminate upper boundary, that is characterized especially by *A. centronotus* (Ulrich and Bassler) and by *A. girtyi* Knight, *A. harltoni* (Cooper), a modified form of *Bairdia dornickhillensis* Harlton (Shaver, 1960, sample 3), *B. oklahomaensis* Harlton, and *Roundyella* cf. *R. simplicissima* (Knight). These ostracods occur with *Fusulinella?* listed elsewhere herein and with the species

Fusulinella iowensis. The lowest positions of this fauna in Indiana are in the limestone and shale above the Buffaloville Coal of the Brazil Formation in Spencer County (locs. 39 and 42), Dubois County (loc. 32), Warrick County (loc. 34), and in the limestone, called the Perth by Hutchison (1960), and associated shale of the Brazil Formation in Owen County (loc. 28). It has also been found extensively in shales associated with limestones, including beds containing the fusulinid *Wedekindellina* (loc. 19), which are in the lower part of the Staunton Formation in Parke and Fountain Counties (locs. 11 and 19). In Illinois, *Amphissites centronotus* was found in limestone near the base of the local Pennsylvanian section on an island in the Des Plaines River, Will County (loc. 4).

The only previously described comparable faunas from the Midcontinent area are Desmoinesian in age; in Ohio and Illinois comparable faunas are found respectively in the Lower Mercer Limestone (middle Pottsville) (Marple, 1952) and in the Seville Limestone Member of the Spoon Formation (Cooper, 1946), also of Desmoinesian age.

Systematic Paleontology

The fusulinid fauna that we obtained from thin sections of limestone over the coal at Burr Mine on Pine Creek in central Warren County (loc. 5), from the limestone in the clay pit north of Veedersburg (loc. 8) in Fountain County, and from limestones associated with the black shales along Square Rock Branch near Port-O-Woods landing field in Parke County (loc. 13) have revealed numerous types of fusulinids, including ozawainellids, *Pseudostaffella, Profusulinella,* and several unidentifiable forms of fusulinids. Although it is not our purpose to describe in this paper all of the faunas encountered in these different limestones, it does seem important that a brief description is published at this time concerning some of them. This seems especially true concerning the new form of *Profusulinella.* It also seems important that we illustrate some of the associated specimens found with this species of *Profusulinella,* including such forms as *Millerella* sp., *Pseudostaffella* sp., and the undescribed form of *Profusulinella* from the limestones exposed in Square Rock Branch, northern Parke County.

Profusulinella burrensis Thompson and Shaver, new species
Pl. 1, figs. 1-10

The shell of *Profusulinella burrensis,* n. sp., is short and inflated fusiform in shape with convex to irregular lateral slopes, slightly shifting axis of coiling, and pointed polar ends. Mature shells of six to seven volutions measure about 2.4 to 3.0 mm in axial length and about 1.0 to 1.3 mm in width, giving form ratios of about 2.4 at maturity. The form ratios of length to width of the first to the sixth volution are about 0.9, 1.1, 1.5, 1.9, 2.1, and 2.4, respectively. The proloculus is almost perfectly spherical and is moderately large. Its outside diameter measures about 86 microns. The heights of the chambers in the first to the sixth volution of the holotype specimen are about 30, 48, 69, 86, 120, and 139 microns, respectively.

The spirotheca is thin and is composed of moderately thick upper and lower tectoria and a distinct central layer, the tectum.

The tunnel is distinct, and its path is straight. The tunnel sides of the chomata are steep to overhanging, and their poleward slopes extend to the axis of coiling in the fourth to the sixth volution of mature specimens, giving the

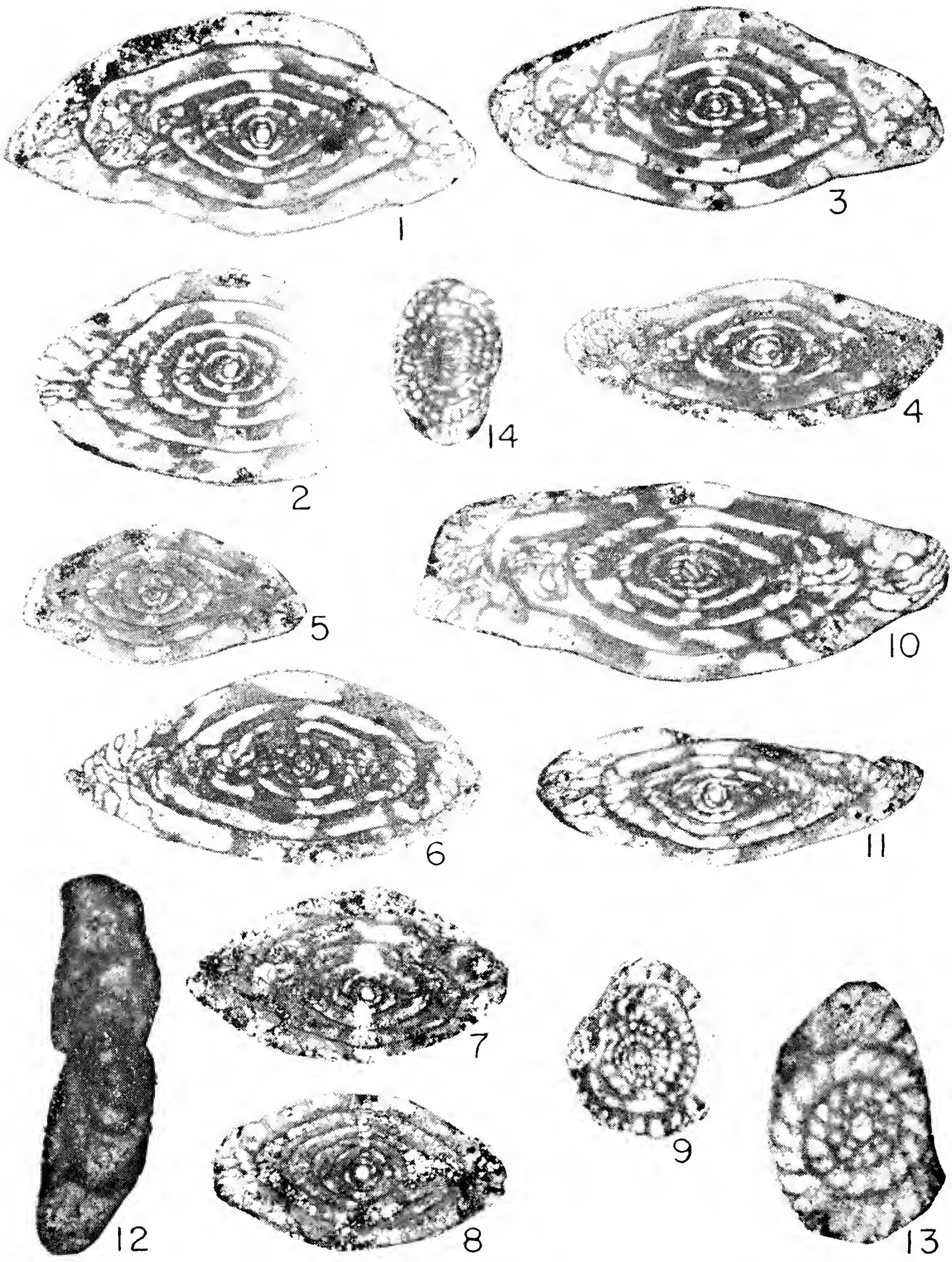


PLATE 1.—Early Pennsylvanian fusulinids.

FIGURES 1-10.—*Profusulinella burrensis* Thompson and Shaver, n. sp. 1, Axial section of the holotype, x 20 (loc. 5); 2,4-7, axial sections of paratypes, x 20 (loc. 5); 3, axial section of a paratype, x20 (loc. 8); 8, axial section of a paratype, x20 (loc. 13); 9, sagittal section of a paratype, x20 (loc. 5); and 10, section tangent to the second volution, x20 (loc. 8).

FIGURE 11.—*Profusulinella* sp. Axial section of an elongate specimen that shows typical wall structure, x20 (loc. 13).

FIGURES 12-13.—*Millerella* sp. 12, Axial section, x100 (loc. 8), and 13, sagittal section, X100 (loc. 13).

FIGURE 14.—*Pseudostaffella* sp. Slightly oblique parallel section tangent to the second or third volution, x20 (loc. 13).

false impression that the shell has axial fillings. The tunnel angle measures about 25, 13, and 40 degrees in the fourth to the sixth volution. The septal counts of the first to the sixth volution are about 10, 14, 15, 19, 21, and 24. The septa are slightly fluted in the extreme polar ends of the shell, but they are unfluted in other parts of the shell.

Remarks. — *Profusulinella burrensis* can be distinguished from *P. kentuckyensis* Thompson and Riggs by its shorter and more inflated shell, distinctly more massive chomata, and its more inflated chambers. Its tunnel angle is considerably smaller for corresponding parts of the shell.

Occurrence.—*Profusulinella burrensis* is abundant in the caprock limestone over the coal at Burr Mine near Pine Creek in central Warren County (loc. 5), and it has been found in the limestone in the clay pit north of Veedersburg (loc. 8) where it is associated with scarce specimens of *Millerella* sp. (Pl. 1, fig. 12). *P. burrensis* is scarce in the limestones along Square Rock Branch in Parke County (loc. 13) where it is associated with *Profusulinella* sp. (Pl. 1, fig. 11), *Millerella* sp. (Pl. 1, fig. 13), and *Pseudostaffella* sp. (Pl. 1, fig. 14).

Repository.—All illustrated fusulinid specimens from this study are catalogued with the Illinois State Geological Survey under the number 33P. All illustrated ostracod specimens from this study are catalogued with the Indiana Geological Survey under the number 7G.

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RECORD OF MISSISSIPPI RIVER DIVERSION IN THE MORTON LOESS OF ILLINOIS

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ABSTRACT.—Diversion of the Ancient Mississippi River in Bureau County, Illinois, by the advancing Shelbyville glacier produced a change in the mineral composition of the loess being deposited on the bluffs of the valley below this point. The stratigraphic position of the change in mineral composition has been identified by X-ray diffraction analyses of the clay minerals. Radiocarbon dates from above and below this stratigraphic position are used to date the diversion at 21,000 ± 500 radiocarbon years.

A geologic event of particular significance produced by the advancing Shelbyville (Woodfordian) glacier in Illinois was the diversion of the Mississippi River from the channel it had occupied at least since the withdrawal of the Illinoian glaciers. This diversion of the Ancient Mississippi River by the glacier has been described and previous work summarized by Shaffer (1954). The location of the ancestral stream as it existed before this major diversion to its modern location is shown in Figure 1, and on a recent map by Frye, Glass, and Willman (1962, p. 8). Evidence of this diversion of the Mississippi River is recorded in the Morton Loess—a body of silt that was deposited, largely by wind action, during the advancing phase of the Shelbyville glacier.

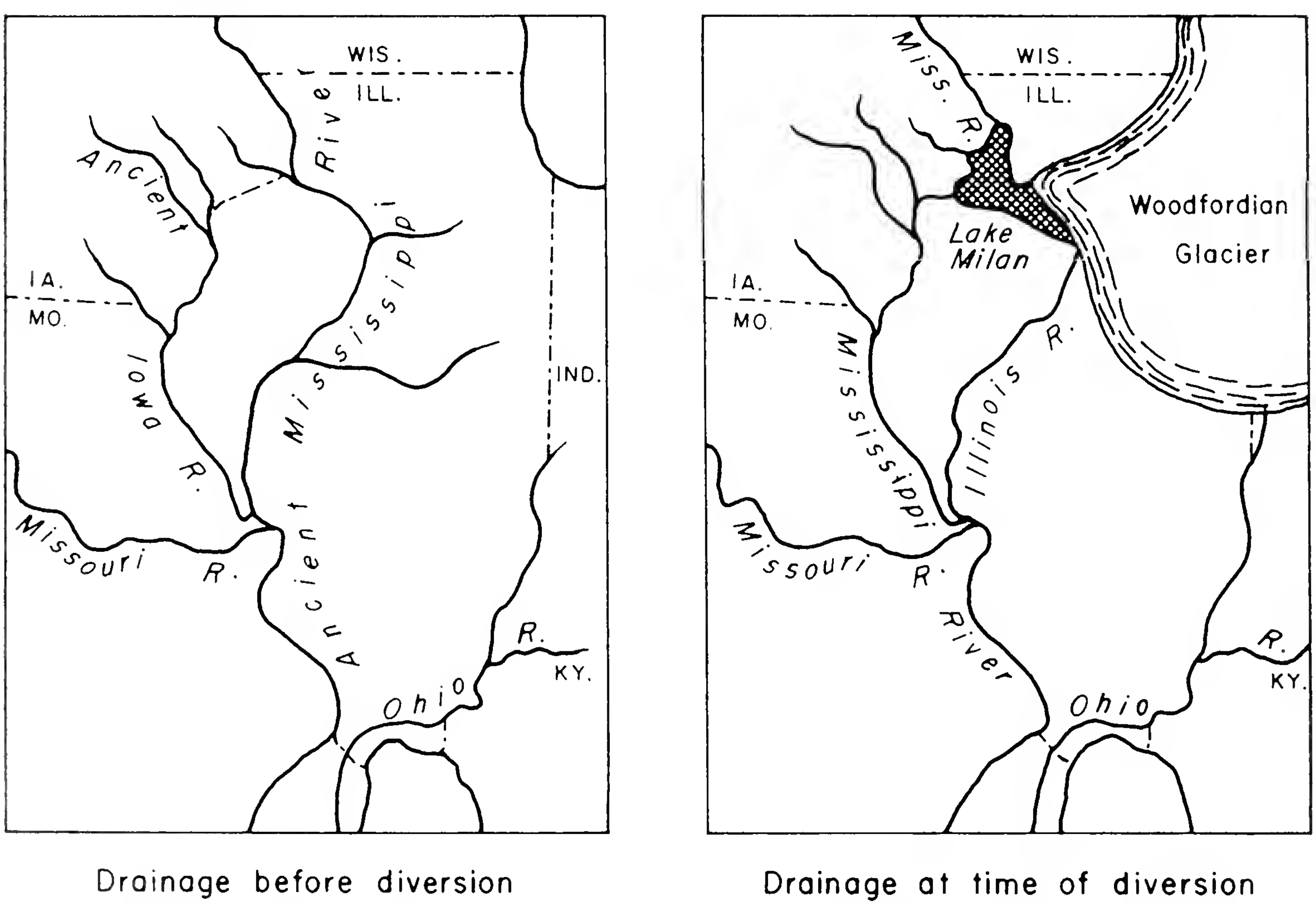

FIGURE 1.—Maps showing the position of Ancient Mississippi River before diversion and at the time the stream was diverted.

Inasmuch as the Morton Loess was deposited during the advance of the Woodfordian glacier and its accumulation at any particular place was not terminated until it was buried beneath the advancing glacier, the point in time when the Ancient Mississippi River was blocked and diverted to its present course falls within the time of deposition of this stratigraphic unit. But, because the Morton Loess consists of eolian silt that was deposited relatively rapidly and essentially continuously, field examination offers no clues, such as a physical break observable in outcrop sections, to mark the time of diversion.

A possible means of defining precisely the point within the Morton Loess that coincides in time with the diversion of the Mississippi River to its present course was suggested by the results of a regional study of the mineralogy of the loesses of Illinois (Frye, Glass, and Willman, 1962). In that study it was shown that the outwash transported by the Ancient

TABLE 1.—Analyses of Samples from Richland Creek and Danvers Sections in Illinois (analyses by H. D. Glass)

Depth (inches) below top of Morton Loess	Sample No.	Magnetic Susceptibility[1]	X-ray diffraction counts per second (bulk sample) Calcite	Dolomite	Percent clay minerals in less than 2 micron fraction Montmorillonite	Illite	Kaolinite and Chlorite
			Richland Creek Section				
Overlying till	P-566	—	20	105	6	64	30
4	P-1354	3.7	14	280	41	37	22
8	P-1353	2.2	38	265	41	36	23
12	P-1352	3.8	58	185	43	34	23
16	P-1351	3.1	18	90	49	32	19
20	P-1350	7.9	—	220	62	21	17
24	P-1349	9.6	5	185	62	22	16
28	P-1348	9.0	10	135	61	24	15
32	P-1347	9.8	—	200	60	24	16
36	P-1346	8.4	—	125	61	25	14
40	P-1345	15.7	—	240	61	25	14
44	P-1344	14.4	6	100	64	22	14
48	P-1343	8.8	—	150	64	21	15
			Danvers Section				
Overlying till	P-558		10	145	10	67	23
4	P-1339		—	90	28	49	23
8	P-1338		7	180	42	34	24
12	P-1337		6	110	37	41	22
16	P-1336		—	85	31	42	27
20	P-1335		7	115	50	27	23
24	P-1334		—	130	52	27	21
28	P-1333		—	120	[2]	[2]	[2]
32	P-1332		—	90	[2]	[2]	[2]
36	P-1331		—	90	50	28	22
40	P-1330		—	80	52	26	22
44	P-1329		—	135	[2]	[2]	[2]
48	P-1328		—	55	52	22	26
52	P-1327		—	45	54	21	25
56	P-1326		—	55	60	19	21
60	P-1325		—	40	66	20	14

[1] Analyses by R. L. Jones, Department of Agronomy, University of Illinois.
[2] Calculation impractical.

Mississippi River was derived in part from the headwaters region of the drainage system that was located to the northwest of Illinois. This outwash was the source material for the Roxana loess in central and western Illinois, and that loess has been shown to contain a high percentage of montmorillonite among the clay minerals. In contrast, outwash in valleys farther east, which derived most of their outwash directly from the Lake Michigan glacial lobe, served as a source for loess with a much smaller percentage of montmorillonite and a much higher percent of illite and chlorite. Furthermore, the tills in the regions to the east and west of the Mississippi show the same contrast in montmorillonite, illite, and chlorite content (Willman, Glass, and Frye, 1963). It is concluded from these facts that along the Illinois River valley of central Illinois, which prior to diversion had been an eastern loop of the Ancient Mississippi, the percentage of montmorillonite in the Morton Loess should be markedly less after the diversion and the resultant decrease in montmorillonite in the outwash. Analyses previously made from the upper and lower parts of the Morton Loess at two sections indicated that the montmorillonite content was significantly lower in the upper part.

To pinpoint the stratigraphic position of the glacial blocking of Ancient Mississippi River within the loess unit, closely spaced samples were collected through the entire thickness of the Morton at sections where the silts and tills above and below had also been studied (Richland Creek Section and Danvers Section of Frye, Glass, and Willman, 1962). These samples were analyzed by X-ray diffraction, using the same methods described for the previous work. In addition, magnetic susceptibility determinations were made for the Richland Creek Section by Dr. R. L. Jones, Agronomy Department, University of Illinois. The results of these analyses are given in Table 1.

The sharp break in montmorillonite content and magnetic susceptibility values is quite apparent between 16 and 20 inches from the top of the Morton and thus there is basis for concluding that the diversion of the Mississippi River occurred only a short time before this distinct mineralogical change appeared in the loess deposit. Mineralogical changes are also known to occur in the lower part of the Peoria Loess beyond the Shelbyville Moraine (Frye, Glass, and Willman, 1962) and it is probable that sufficiently detailed sampling and analysis of the lower part of the Peoria in the lower Illinois Valley would define the precise stratigraphic position of the diversion.

A particular problem exists in any attempt to equate time with stratigraphic position within any unit that has been overridden by a glacier. In this study we have met this problem by utilizing sections where fossil moss occurs in place at the top of the Morton Loess and below the Shelbyville till, thus showing that the Shelbyville glacier passed over the probably frozen Morton Loess without eroding it. Also, there may have been a decrease in rate of deposition of the Morton after the glacial blocking deprived the Illinois Valley of part of its source of outwash.

The advancing Shelbyville glacier approached the broad valley of the Ancient Mississippi at an oblique angle and the event of blocking and diversion required some years for completion. Ponding of the drainage formed a lake, called Lake Milan by Shaffer (1954), and overflow from this lake at the col west of Rock Island established the Mississippi River in its present position. Although some material from the northwest may have continued to be available for transportation down the ancient course the amount was substantially reduced after the ice dam was complete. Furthermore, during the deposition of the lower part of the Morton Loess while the Ancient valley was unrestricted, significant quantities of outwash from the advancing Lake Michigan lobe glacier must have been incorporated in the deposits of the source valley. Both before and after the diversion an unknown quantity of sediment was contributed to the valley by erosion of local bedrock and earlier Pleistocene deposits, the latter of which contained some montmorillonite. Furthermore, an increment of the Morton Loess was undoubtedly derived from "blow over" from the Mississippi Valley a short distance to the west, and some of the montmorillonite was derived from alteration of chlorite to vermiculite, part of which is indistinguishable from montmorillonite. For these reasons the contrast in the mineral composition of the upper and lower parts of the Morton Loess is much less than the contrast in the mineral composition of the tills from the western source and those from the Lake Michigan lobe (Willman, Glass, and Frye, 1963). Nevertheless, the sharp discordance in mineral composition shown by the analyses listed in the table serves to define the point of major change in outwash source.

Placement of the diversion in this stratigraphic position furnishes a basis for placement in time. Radiocarbon dates from central Illinois (Frye and Willman, 1960), including dates from the Danvers Section that was sampled, indicate that the top of the Morton is only slightly older than 20,000 radiocarbon years B.P. Also, dates from the Farmdale silt that occur immediately below the Morton Loess indicate that Morton deposition could not have started before 22,000 to 22,500 radiocarbon years B.P. These limiting dates, together with the stratigraphic evidence, indicate that the Mississippi River was diverted to its present course by the advancing Woodfordian glacier 21,000 ± 500 radiocarbon years B.P.

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GROWTH AND PIGMENT STUDIES OF *PULLULARIA PULLULANS*

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ABSTRACT. — Growth and pigment formation of *Pullularia pullulans* were studied in various media. Lactose was an excellent source of carbon; the logarithmetic growth phase required 15-16 hours. The utilization of glucose by the organisms was slightly higher than that of fructose. Vitamins, especially thiamine, enhanced growth but were not essential to it. The organism did not grow in a mixture of 21% oxygen-79% helium. The addition of nitrogenous compounds to media containing maltose or glucose enhanced pigment production, but the yield was lower with the glucose system. Cultures shaken at room temperature (25°C) produced much more pigment per unit time than cultures incubated without shaking at 30°C. No pigment was formed when the organism was grown in basal media containing yeast extract alone or yeast extract plus malt extract. A procedure was devised for extracting the pigment from the cells. The pigment behaved as an indicator, changing color upon addition of acid or alkali.

The genus *Pullularia* is a yeast-like fungus widely distributed in nature (Bauer, 1938; Clark, 1957; Cook, 1958). It is important industrially because it is involved in deterioration of paint and discoloration of lumber and is injurious to plants and plant products.

The published information about the organism is scanty and conflicting. Its taxonomy is uncertain and practically all isolates are assigned to the species *P. pullulans*. The reports on its utilization of lactose are not in agreement (Negroni and Fisher, 1942; Clark and Wallace, 1958).

In the present research, utilization of carbohydrates by *P. pullulans* strain NRRL YB 4515 was investigated, and various carbonaceous and nitrogenous compounds were tested as sources of carbon and nitrogen, respectively. The effect of vitamins on growth was determined, and the extent of pigment formation was evaluated.

MATERIALS AND METHODS

The amino acids, vitamins, salts and sources of carbon were of high purity or reagent grade.

The basal culture medium contained 0.3% yeast extract plus 0.5 to 6% lactose, 5% glucose, or 5% fructose. From a 48-hr culture of *P. pullulans*, 1.5 X 10^6 cells were added per ml of basal medium, the initial pH being 5.4. For 15 days fifty-ml suspensions in 125-ml flasks were incubated at 30°C without shaking or were mechanically shaken at room temperature (25°C). For each of the carbohydrates a total of 64 flasks, including controls, were used. Each flask was reconstituted daily to its original volume by the addition of water. Cell counts were made hemocytometrically and by plate counting. The daily rate of carbohydrate utilization was determined by the Nelson (1944) modification of the Somogyi method (1945).

The ability of the organism to utilize various compounds containing 2,3,4,5 and 6 carbon atoms and a number of nitrogen sources was tested by employing Bacto yeast nitrogen base media (Difco 392) and

Bacto yeast carbon base media (Difco 391), respectively. The vitamin requirements were tested in Bacto yeast vitamin free base media (Difco 394). The culture in amounts of 0.10 ml containing 1.5 X 10^6 cells per ml of suspension was added to tubes containing 10 ml of the media described above. Half of the tubes were incubated at 30°C without shaking, and the remainder shaken at room temperature. Cell counts were determined by plate counting. Growth and pigment formation were measured turbidimetrically according to the Wickerham method (Wickerham and Burton, 1948; Wickerham, 1951).

Nitrogen fixation was tested in Bacto yeast carbon base medium with cells which had been transferred three times in a medium containing only maltose. Fifty-ml suspensions containing 1.5 X 10^6 cells per ml were added to 125-ml flasks with side arms provided with pressure tubing and stopcocks. The flasks were plugged at each end with sterile cotton and were exposed to 21% oxygen-79% helium. The control flasks were exposed to air. Pairs of flasks were incubated at 30°C without shaking and incubated at room temperature with shaking. Air entering the system was passed through 2 *N* sulfuric acid to trap ammonia, if any.

To study pigment formation, 1.5 X 10^6 cells from a 48-hr culture were added per ml of various media. Fifty-ml suspensions were incubated at 30°C without shaking, shaken at room temperature, or shaken at 36-40°C. The 8-day-old suspensions were centrifuged and the intensely colored supernate decanted. The cells were washed three times with 0.9% sodium chloride, three times with distilled water, and were dried in thin layers. The resulting dried mass was extracted five times with 1.25 *N* sodium hydroxide, centrifuged, and the supernate decanted. The extract was neutralized with hydrochloric acid

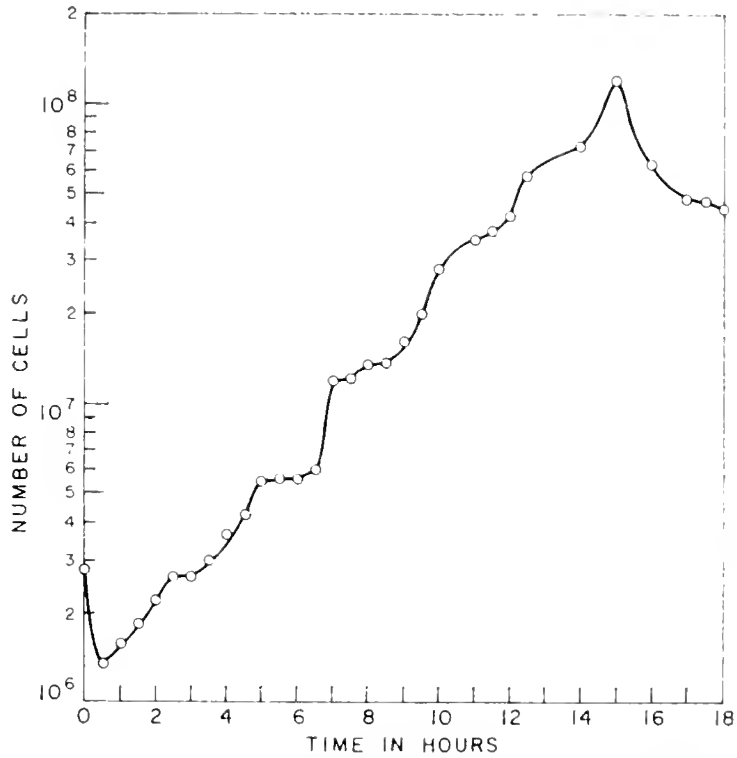

FIGURE 1.—Growth curve of *P. pullulans* on 5.0% lactose medium.

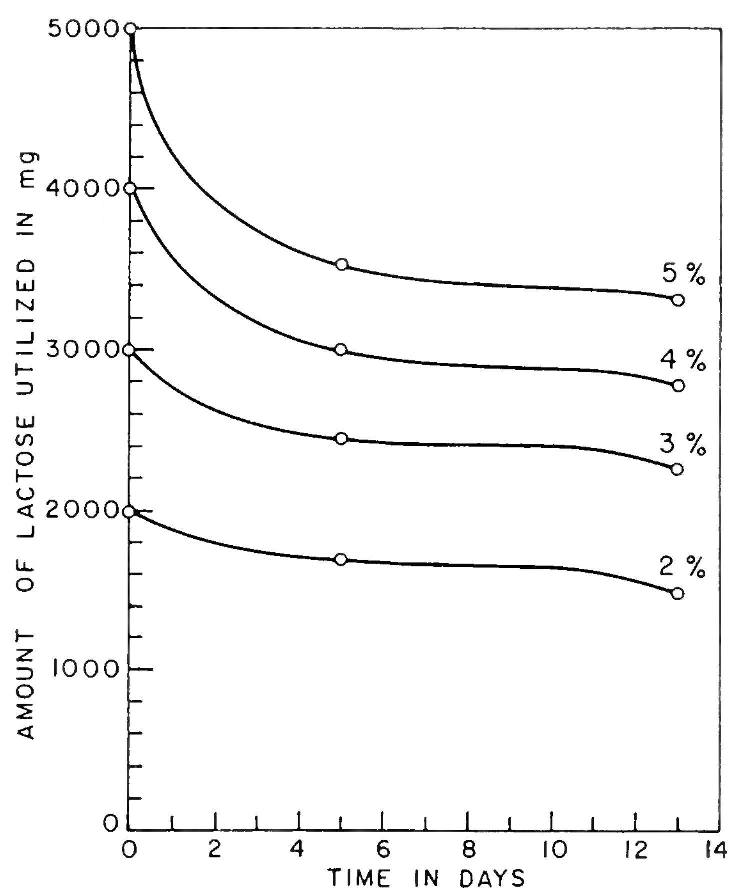

FIGURE 2.—Utilization of lactose by *P. pullulans*.

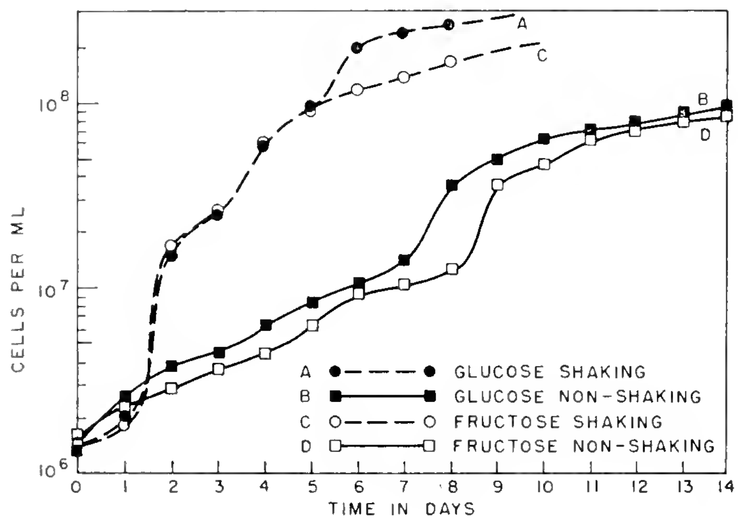

FIGURE 3. — Cell counts of *P. pullulans* in glucose and fructose media.

and dialyzed in cellophane against water until free of chloride. Excess acetone was added to the dialytic residue and the precipitated pigment removed by centrifugation.

To determine the effect of salts on pigment formation in 5% glucose or 5% maltose, NH_4Cl, $(NH_4)_2SO_4$, $MgSO_4$, K_2HPO_4, KH_2PO_4, NH_4NO_3 and KNO_3 were added singly or in mixtures, each at a concentration of 0.05% in shaken and incubated series.

Results and Discussion

Growth and Carbohydrate Utilization. Maximum growth of *P. pullulans* NRRL YB 4515 and utilization of lactose occurred in media containing 0.3% yeast extract plus 5% lactose (Figures 1 and 2). The daily cell counts in media containing 0.3% yeast extract plus 5% glucose or fructose are shown in Figure 3. The lowest pH, 3.40, was found in suspensions shaken at room temperature (Figure 4). The organism utilized more of each carbohydrate when shaken at room temperature than when incubated without shaking at 30°C (Figure 5). The ability of the organism to utilize lactose was confirmed by determining the rate of lactose utilization in media containing 2 to 5% lactose and by determining its logarithmic phase (15-16 hr; Figures 1 and 2). In both the shaken and the incubated series containing glucose and fructose, slightly more of the glucose was consumed.

Carbon Compounds. When 4% sodium succinate was added to the Bacto yeast nitrogen base media (Difco 392), growth was abundant and pigment formation heavy after 120 hr. Growth was good in the presence of 2% asparagine plus 2% ammonium acetate, very poor with 2% pyruvic acid or 3% sodium glutamate plus 3% sodium formate, and absent with 2% fumaric acid plus ammonium acetate or 2% glycine plus 2% ammonium acetate. Pigment was not formed with the as-

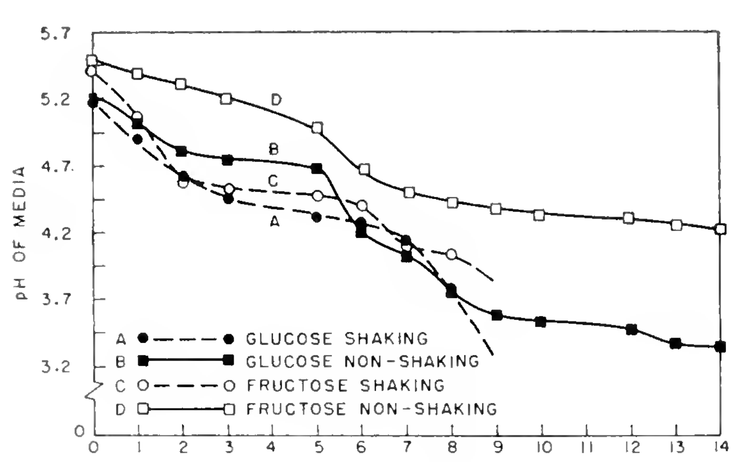

FIGURE 4. — pH changes during glucose and fructose utilization by *P. pullulans*.

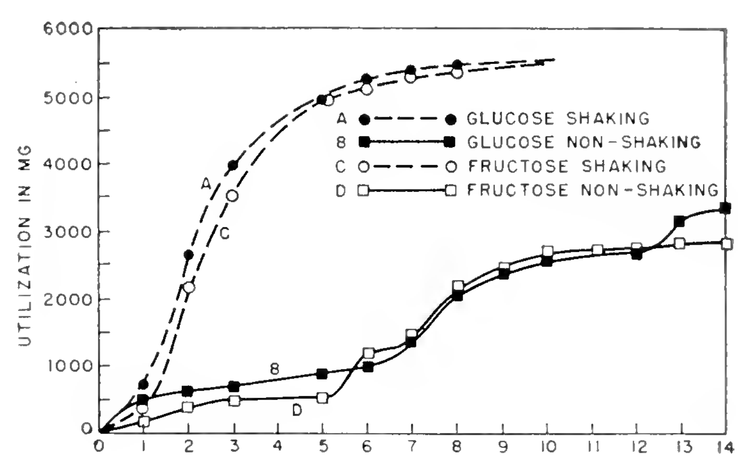

FIGURE 5. — Utilization of glucose and fructose by *P. pullulans*.

TABLE 1.—Effect of 0.05% Nitrogenous Salts on Growth and Pigment Production of *P. pullulans* in Bacto Yeast Carbon Base (Difco 391).

Test Salts	Growth								Pigment			
	Shaken at Room Temperature				Unshaken at 30°C				Shaken at Room Temp.		Unshaken at 30°C	
	24 hr	48 hr	72 hr	96 hr	24 hr	48 hr	72 hr	96 hr	24 hr	96 hr	24 hr	96 hr
$(NH_4)_2SO_4$	3+	6+	8+	8+	—	3+	6+	6+	—	2+	—	1+
NH_4Cl	1+	4+	8+	8+	—	2+	6+	8+	—	2+	—	1+
NH_4NO_3	3+	6+	8+	8+	3+	5+	6+	8+	—	1+	—	—
$MgSO_4$	1+	1+	2+	2+	1+	1+	1+	1+	—	—	—	1+
KNO_3	4+	6+	8+	8+	—	1+	1+	8+	—	3+	—	—
K_2HPO_4	—	1+	1+	1+	1+	1+	1+	2+	—	—	—	—
KH_2PO_4	—	1+	1+	1+	—	1+	2+	2+	—	2+	—	1+
$NH_4Cl + MgSO_4$	3+	6+	8+	8+	—	2+	2+	8+	—	2+	—	1+
$NH_4Cl + MgSO_4 + KH_2PO_4$	3+	5+	6+	8+	2+	4+	5+	8+	—	3+	—	—
Controls	—	1+	2+	4+	—	—	1+	3+	—	—	—	—

The 8+ is maximal growth and pigment production, determined turbidimetrically;
Dash indicates no growth or pigment production.

paragine-ammonium acetate mixture. Heavy growth and pigment formation occurred with 4% glycerol or 5% sodium citrate. The 4-carbon compound fumarate, alone or with ammonium acetate, was not utilized, whereas succinate was an excellent source for growth and pigment formation.

Nitrogen Sources. When 2% asparagine, aspartic acid, cysteine, glycine, glycylglycine, leucine, lysine, glutamic acid, methionine, or creatine was added to the basal medium, growth and pigment formation were extensive after 106 hr. However with 2% tyrosine the growth rate was comparably great, but the pigment was yellow instead of black. The effect of 0.05% of various inorganic nitrogenous salts in Bacto yeast carbon base (Difco 391) is shown in Table 1. Among the nitrogenous substances tested, asparagine and glycylglycine enhanced most the growth and black pigment formation.

Vitamins. The following vitamins, added to the vitamin-free yeast base media (Difco 394), singly or in various combinations in the concentrations suggested by Wickerham (1951), produced maximum growth after 10 hr: biotin, calcium pentothenate, folic acid, inositol, niacin, riboflavin, thiamine hydrochloride, pteroylglutamic acid, and pyridoxine hydrochloride. Thiamine was the most effective single vitamin. Growth also occurred in the vitamin-free base medium but at a definitely reduced rate. The fact that the organism grew in the absence of vitamins, though more slowly, may indicate that it can synthesize them.

Nitrogen Fixation. No growth occurred after 120 hr in the flasks treated with the oxygen-helium mixture. When atmospheric air, passed through $2N$ H_2SO_4, was admitted to these flasks, growth was evident in 48 hr, and pigment in 96 hr. The control suspensions showed growth after 48 hr and pigment after 72 hr. Accordingly these findings substantiate the reported ability of *P. pullulans* to fix nitrogen from the air (Brown and Metcalf 1957).

Pigment. Formation.—Of all the media tested the one containing 5% maltose plus 0.3% malt extract produced the largest amount of pigment. A lower yield of pigment resulted in the shaken series when in this medium 1% glucose, fructose, galactose or sucrose was substituted for the 0.3% malt extract. Even less pigment resulted when the maltose was decreased to 2.5% and the above named sugars were increased to 2.5%.

Minimal pigment formed in media containing 5% maltose plus the nutrient salts recommended by Wickerham (1946). Pigment was absent in media containing 5% maltose plus 0.3% malt extract, 2.5% maltose plus 0.3% yeast extract, or 2.5% maltose plus 0.3% yeast extract plus 0.3% malt extract.

Inorganic salts were found to affect pigment formation in 5% glucose or 5% maltose. In the shaken and the incubated series containing 5% glucose only slight pigment formation was noticed with NH_4NO_3 + $MgSO_4$ or NH_4Cl + KH_2PO_4 + $MgSO_4$. No pigment was formed with $MgSO_4$ alone or in an admixture with either K_2HPO_4 or KH_2PO_4. In the series with 5% maltose, pigment formation was moderate only with $MgSO_4$ alone or in an admixture with either K_2HPO_4 or KH_2PO_4, but was abundant with the other salts. Maltose containing $(NH_4)_2SO_4$, NH_4Cl, NH_4NO_3 or KNO_3 and shaken at 36-40°C produced the highest amount of pigment.

Properties of the Pigment.—The dry pigment occurred as brown to black flat scales. It was more soluble in hot than in cold water, less so in butanol and in 40% methanol, and insoluble in ether, acetone, benzene and chloroform. The addition of base to an aqueous solution produced a green coloration, and on acidification the solution changed to red. The pigment gave a positive Molish test and showed no reducing properties.

Microscopic Studies. — Pigment formation starts at the inner cell wall and spreads uniformly toward the center, filling the entire cell space in 8 to 10 days. The color *in situ* varies from light brown to jet black. The oval cells rupture at one end, and infrequently at both ends. Irregularly shaped fragments of pigment and debris are visible after several days. The older the culture, the more numerous are the pigment fragments and debris. When growth occurs to the exclusion of pigment formation, the cells are intact and only little debris is present. The locus of expulsion of the pigment can be followed distinctly.

Acknowledgments

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CHEMISTRY EDUCATION AT THE INTERMEDIATE GRADE SCHOOL LEVEL

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ABSTRACT. — A completely new approach to the teaching of chemistry has been developed over a period of eleven years at the Lake Villa [Illinois] Consolidated Grade School. As a result, it can be said that chemistry can be as effectively taught in the grade school as any other subject.

Chemistry is a subject that can be effectively taught in the grade school. This conclusion is based upon a program of research now entering its twelfth year at the Lake Villa [Illinois] Consolidated Grade School. As a result of this study, a system of six-week units of instruction in the field of chemistry for the third through the eighth grades, with a final quantitative unit for students showing exceptional ability and aptitude, has evolved. Experience with units for the sixth, seventh, and eighth grades has been reported (Midgley, 1958). The present report is concerned with the overall objectives of this work and the techniques we have used to achieve them.

OBJECTIVES OF GRADE SCHOOL CHEMISTRY

1.—To fill a serious deficiency in the science curriculum. An inspection of the standard textbooks of general science selected by individual teachers on a preferential basis and used during the 1961-2 academic year at our school from the third through the eighth grades shows that of a total of approximately 1800 pages in these books, only 70 are devoted to purely chemical concepts. A major part of the experimental demonstration of these concepts is noted to be limited and repetitious from grade to grade, for example, extinguishing fire with carbon dioxide.

2.—To feed, nourish, and guide the natural curiosity most children have in matter and its changes. To the young, inquiring mind, the many kinds of matter and the thousands of possible changes they can undergo, that is to say the subject of chemistry, should be at least as interesting and important as any other scientific subject. Even without formal training, many children acquire an interest in chemistry which becomes most intense when they are ten to twelve years old. A formal course before a student reaches this age level may prevent the student from attempting dangerous experiments with commercially available sets.

3.—To psychologically prepare a student for future study of chemistry. The young mind is receptive to new concepts. A course at the grade school level creates a familiarity with the concepts of chemistry which should make the subject more appealing in high school or college. As a consequence, the number of science-oriented citizens, as well as scientifically trained workers, would be increased.

PEDAGOGICAL CRITIQUE

A completely new approach to the subject of chemistry has been developed for presentation in the elementary grades. We are of the opinion that the systems developed for secondary and collegiate levels made the subject unnecessarily difficult and completely unsuited to grade school instruction. A résumé of the chief obstacles which we have avoided follows.

1.—Excessive emphasis upon theory without first establishing facts. In our curriculum, the facts of chemistry are first qualitatively given. Theoretical and quantitative aspects are then secondarily introduced when, and only when, they can effectively serve to explain or add to the facts thus established.

2.—Pure memorization of concepts without any real understanding. In our course we have tried to unfold the study in a natural manner, introducing no new concept without the student being ready to understand it by what has already been learned in the course. The type of technique which is avoided, for example, is that of presenting the standard preparation of oxygen from potassium chlorate without any prior mention of the halogen compound. If a student's curiosity is aroused, it may be thwarted, for some elementary textbooks make no further reference to the starting compound.

3.—Chemistry as an abstraction. The immature mind is not prepared to absorb concepts in the abstract and should the subject be thus presented, the student may obtain the impression that chemistry is a subject of signs and symbols alone with no relation to real matter. In this course every attempt has been made to illustrate by actual experiment each and every principle taught. In order to do this, rapid procedures, using primarily microtechniques to illustrate a point, were worked out. A simple apparatus was also designed to quickly illustrate all of the gas laws and to serve as well as a barometer or a gas thermometer.

4. Complex organization with subtle interdependence. The standard textbooks for the presentation of chemistry at a secondary or collegiate level present a format with no obvious order or connection between the units to one untrained in the field of chemistry. We reasoned that, if grade school children are to be taught chemistry by grade school teachers, there must be a simpler organization of the material.

The Curriculum

The complete outline of our curriculum is given in Table 1. The details of the work for grades 6 through 8 is given since it has been found beneficial to modify the original presentation (Midgley, 1958). The subdivisions of the quantitative unit are given separately in Table 2. While Unit 1 is the correct prelude for an integrated elementary course in chemistry, the remaining units could be presented without it, providing one avoids the obstacles previously mentioned. Even Unit 5, if necessary, could be presented with little reference to the preceding units. Such independence is important in the grade school, where instruction is necessarily piecemeal, as contrasted with the continuity of a subject taught in high school or college.

1.—Unit 1. Writing a textbook of any kind for the lowest grades requires a different language and technique than would be used for the

Table 1.—Grade School Curriculum Outline.

I. *Unit 1. Matter in General* (3rd, 4th, and 5th Grades)
- A. Matter, the subject of chemistry
- B. Changes in matter, physical and chemical
- C. Kinetic Molecular Theory of matter
- D. Nature of pure matter
- E. Mixtures of matter
- F. Separations of mixtures of matter

II. *Unit 2. Elements-Building Blocks of Matter* (6th Grade)
- A. "Student's Periodic Table"
- B. Classification of the elements and their properties
  1. Metals
  2. Nonmetals
  3. Hydrogen
- C. Direct means of identification of the elements
  1. Color of solutions
  2. Color of flames
  3. Bead tests
  4. Spectroscopic Analysis
- D. Theory of the structure of the atoms of the elements

III. *Unit 3. Compounds-Chemical Combinations of Elements* (7th Grade)
- A. Classification of compounds
- B. Formation of compounds
- C. Properties of compounds
- D. Theory of the formation of compounds

IV. *Unit 4. Families of Elements and Their Compounds* (8th Grade)
- A. Hydrogen and its compounds
- B. Metal families and their compounds
- C. "Cousins" and their compounds (Group VIII metals)
- D. Nonmetal families and their compounds
- E. Organic Compounds

V. *Unit 5. Quantitative Measurement of Matter*

higher grades. The material must be related to the experience of the pupil. While the overall outline as given serves the purpose of defining the subjects to be covered, the language and method of presenting that material must necessarily be suited to the age group being instructed. It has been found that words, however difficult they may seem to grownups, are not in the least disturbing to the youngster of any age, providing he has the meaning given to him first. If this meaning of a concept is provided in terms with which he is familiar and can understand, and then related to some common experience of his, a label that will be easily remembered can then be attached to the meaning. Thus, in this unit, such concepts as the meaning of chemistry, the properties of matter, the difference between law and theory, etc., are taught with a great deal of success. Some of the subjects, which at first thought appear to be too difficult for the third grade, evoked the most spirited discussion in the first trial use of this material.

2.—Units 2-4. Several important changes have been made in the original order of presentation (Midgley, 1958). The theory of the structure of matter has been taken from the last of these units and placed in Unit 2 as the final lesson. It was independently discovered by several

TABLE 2.—Quantitative Unit Outline.

I. *Methods of Counting and Recording Units of Matter*
  A. Numbering systems
  B. Recording of numbers
    1. Decimal system
    2. Significant digits
  C. Manipulating of numbers
    1. Logarithms
    2. Slide rule

II. *Measurement of Matter Generally*
  A. Dimensions of matter
    1. Size
    2. Weight
  B. Density of matter
    1. Solids and liquids
    2. Gases
  C. Metric units used in the measurement of matter
    1. Units of length
    2. Units of volume
    3. Units of weight
    4. Energy units used in the measurement of matter

III. *Measurement of Pure Substances-Formulas*
  A. Subscripts and coefficients
  B. Atomic weight and gram atomic weight
  C. Fomula or molecular weight and gram formula or gram molecular weight
  D. Formula fractions and percentage composition
  E. Simplest formula from percentage composition
  F. Avogadro's Number

IV. *Measurement of Gases*
  A. Avogadro's Law
  B. Boyle's Law
  C. Charles' Law
  D. Dalton's Law
  E. Guy Lussac's Law
  F. Density of Gases
  G. Kinetic theory of gases and Graham's Law of diffusion

V. *Measurement of Molecular Solutions*
  A. Molar solutions
  B. Molal solutions
  C. Percent solutions
  D. Density of solutions
  E. Percent compared to density
  F. Dilute from concentrated solutions

teachers that this theory could be easily taught, with considerable interest, once the student had an understanding of the Periodic Table as given in Unit 2. The theory of the formation of compounds has been added to Unit 3, and concepts related to nuclear energy have replaced the deleted lesson on the theory of the structure of matter.

3.—Unit 5. The initial trial of the quantitative unit has proved particularly pleasing. Members for this class were selected from the 7th and 8th grades on the basis of interest shown in the other units and their superior standing in their respective classes in mathematics. The class was held after school and was well attended throughout the six-week course.

It may appear that we are covering some material that would ordinarily be too difficult for a grade school youngster. However, we never have prejudged what concepts the youngsters will be capable of assimilating. We have tried every concept ordinarily given freshman college students and have then formed the units, finally, by including only those concepts which were found most teachable and useful, keeping the prescribed objectives constantly in mind.

We were agreeably surprized by the enthusiasm with which these exceptional students learned to use the slide rule. This was facilitated partly by making use of a mechanical method of finding the decimal point instead of attempting the mental survey method commonly used by older students in high school and college. Though we taught them the use of the C and D scales only, many were not satisfied and wanted to know about the use of the other scales as well.

As part of their course of instruction, the students of this class prepared solutions of prescribed molarity for use in the next year's classes. It is our belief, because of the success of this year's trial, that we will not need to be so strictly selective in setting up future classes.

Acknowledgment

The author is indebted to Mrs. Mary Berg and Mr. Blaine Thorpe for the initial presentation of Units 1 and 5, respectively.

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Manuscript Received May 15, 1962.

A METHOD FOR RAPID EXTRACTION OF SUGAR FROM CORN STALK TISSUE

H. O. BETTERTON AND A. J. PAPPELIS
University of Maryland and Southern Illinois University

ABSTRACT. — A three minute homogenization of corn pith tissue killed in 80 per cent ethanol and stored for twenty four hours, extracted about 99 per cent of the total sugars. This high level of extraction was consistent in five sampling dates beginning before tassle elongation and ending two months after silking. Centrifugation of the lead precipitate obtained during the clearing stage of sugar analysis decreased the time required per sample by elimination of filtration and washing of the precipitate.

Traditional methods for extracting sugar from plant tissue involve laborious procedures using either a Soxhlet extractor or repeated extraction of the tissue with 80% ethanol, decantation of supernatants, and combination of resulting fractions (Association of Official Agricultural Chemists 1945, 1960; Loomis, 1926, 1935; Paech and Tracey, 1955). Thomas, et al (1949) have reported that sugar can be extracted from a wide variety of plant tissues by grinding them in a Waring Blendor with 200 ml of 70% ethanol for seven minutes. This procedure was reported to be as good as the A.O.A.C. method. However, Thomas, et al sampled young succulent plants and no evidence was presented that sugar could be extracted as easily at other stages in the life cycle. Furthermore, they did not work with corn stalk tissue. Pappelis (1957) found that more than 97% of the reducing sugars (measured as glucose) and nearly 100% of the sucrose (sucrase hydrolyzable fraction) could be extracted from entire internode tissue of mature corn killed in 80% ethanol, stored for four to six months and homogenized for four minutes in fresh, hot ethanol using an Omnimixer. Chemical analysis of aliquots from combined filtrates and original killing fluid and from the extracts of the residues (collected after 36 hours of Soxhlet extraction) were used to determine the per cent extracted by the Omnimixer. The length of time required after killing to obtain this level of extraction was not ascertained. This paper presents data to: determine the time required after killing for a high level of extraction using a three minute homogenization period; eliminate the filtration step in clearing; and, determine the reliability of this method for extraction of sugars from stalk pith tissue at various stages of maturity.

MATERIALS AND METHODS

Seeds of corn (*Zea mays* L.) var. Wf9x38-11 were planted on the Southern Illinois University Agronomy Farm May 21, 1962. Samples were taken at five times during the growing season and represented various stages of growth. Approximately 50% of the plants had one or more inches of silks exposed on July 30. Stalk samples, always collected at noon, consisted of the first through the sixth fully elongated internodes above the uppermost brace roots. The six internodes were removed to exclude all nodal tissue and a longitudinal cylinder of pith tissue was

TABLE 1.—Per cent of sugar extracted by use of the Waring Blendor.

Date of sample collection	Hours after killing	Per cent recovery: Reducing sugar	Sucrose	Total sugar
July 10[1]	0	99.0	100.0	99.4
	24	100.0	96.5	99.6
	48[3]	100.0	98.2	99.6
July 22[1]	0	98.0	98.5	98.1
	24	99.2	100.0	99.3
August 7[2]	0	98.4	99.8	99.5
	24	98.0	100.0	99.6
Sept. 6[2]	0	95.6	99.8	99.0
	24	98.0	99.6	99.4
Oct. 7[2]	0	96.0	99.6	99.4
	24	97.0	99.6	99.2

[1] Average of 6 Replicates.
[2] Average of 5 Replicates.
[3] On subsequent sampling dates, 48 and 72 hour extractions were not significantly greater than the 24 hour extractions.

removed along the central axis using a cork borer 1 cm in diameter. Each cylinder was cut to 6 cm lengths, and then into six pieces, each 1 cm in length. Each of these six pieces were placed into separate storage jars together with 50 ml of boiling 80% ethanol. This procedure provided for samples of tissue from the upper to the lower internodes in each of the six jars. It was repeated with tissue from additional plants until each of the six jars contained from 10 to 15 segments. Twenty-four such jars were prepared on each date. Six of the jars were selected randomly for each treatment in which the tissue was homogenized immediately, 24, 48, or 72 hours after killing. In each, a quantitative transfer was made into a Waring Blendor with a final volume of about 150 ml of 80% ethanol (room temperature). The tissue was homogenized at high speed for three minutes with a stop after one or two minutes to allow the sides of the blendor jar to be washed down with more alcohol. The slurry was filtered through Whatman No. 1 filter paper on a Buchner funnel. The blendor jar and residue were rinsed five times with 80% ethanol, and the filtrate so obtained was returned to the original sample jar after dilution to a standard volume. The tissue residues and filter paper were placed in a Soxhlet extractor with 80% ethanol and extraction allowed to proceed for 36 hours. Soxhlet extracts were collected and diluted to volume.

Suitable aliquots of ethanol from the homogenized sample or Soxhlet extract were evaporated almost to dryness, diluted to 50 ml with distilled water, and cleared according to the method described by Loomis (1926). After 10 minutes, 10 ml of dibasic potassium phosphate (125 g per liter) were added to precipitate the excess lead and the solution was brought to a volume of 100 ml. The precipitate was removed from suspension by centrifugation at 3000 rpm for four minutes.

Reducing sugars were analyzed according to the method described by Hassid (1937), and are reported as glucose. Sucrase was prepared according to the method described by Loomis and Schull (1937) and, following hydrolysis, added reducing sugar was determined and calculated as sucrose.

Experimental Results and Discussion

The data for sugar extraction are presented in Table 1. The grinding procedure extracted over 99% of the total sugar after 24 hours in the alcohol. The extraction never exceeded 99.6% for total sugar, even at 72 hours after killing. Evidently, there was a small amount of sugar which could not be extracted by grinding and rinsing of the residues on the funnel that could be removed from the residues by 36 hour Soxhlet extraction. This high degree of extraction was consistent throughout the study which included young succulent tissue of the stalk prior to tassle formation to dry stalk samples.

The advantage of this system over others lies in the reduced amount of extraction and handling time required per sample. In addition, collection and killing of tissue in routine studies with many samples can be followed in 24 hours by the extraction step.

Although the evaporation of alcohol from sample aliquots was completed as described, another time-saving step was incorporated in the clearing procedure. Filtration and washing of the lead phosphate precipitate obtained from deleading, which required much bench space and time, was eliminated by centrifugation of the precipitate. The pellet of the precipitate did not include any Soxhlet extractable sugar and occupied less than 1 ml of volume. The clear supernatent was decanted and aliquots for reducing sugar and sucrase hydrolyzable sugar were processed according to the normal procedure.

Acknowledgments

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NEWS AND NOTES

Do not be misled by appearances; the Transactions will not be issued monthly. Hereafter, barring the unavoidable and understandable delays in printing, the Transactions will appear on or near the middle of March, June, September and December. Such scheduling means planning far ahead. Consequently, I think I can say that authors should expect their papers to be "in the works" for approximately nine months. Last minute items for News and Notes will be a regular exception, of course, to that period of time.

Some members have expressed interest in the procedures for handling manuscripts. All manuscripts coming to the editor get a number and a record sheet. Pertinent information, such as date received, reviewer, mailing dates and actions are recorded (except when the system breaks down). Manuscripts are sent to members of the Editorial Board or, on their recommendation, to other qualified persons for evaluation and critical editing. If the paper is not rejected there comes a period of time wherein an exchange of ideas, remarks, etc., takes place between the editor and author, based upon the recommendations of the Editorial Board and the dictates of editorial whimsy. Once something is hammered out that suits the editor and is accepted by the author, the manuscript is prepared for the printer. When enough copy has accumulated to make an issue—off it goes—eventually reaching the printer. Therefore, it is obvious that a well-written paper, needing little attention, can be published sooner than a paper that must be reworked and reworked again.

Southern Illinois University has reported new appointments in Science as follows: Dr. Dan Miller, formerly in the petroleum industry and now Associate Professor in the Geology Department (sedimentation); Dr. Ronald Brandon, formerly of the University of Alabama, Assistant Professor of Zoology (taxonomic herpetology); Dr. DuWayne Englert, formerly of Purdue University, Assistant Professor of Zoology (population genetics); Dr. Hermann J. Haas, formerly of the Rockefeller Institute and the University of Minnesota, Associate Professor of Zoology (experimental embryology); Dr. Andrew Hendrickx, formerly of Kansas State University, Assistant Professor of Zoology (descriptive embryology); and Dr. Harold J. Walter, formerly University of Michigan, Assistant Professor of Zoology (malacology).

ACADEMY BUSINESS

SECRETARY'S REPORT FOR THE YEAR

APRIL 28, 1962-APRIL 25, 1963

ANDREAS A. PALOUMPIS, *Secretary*

COUNCIL MEETINGS

The Council held four meetings during the year, as stipulated in the Constitution.

First Council Meeting. This was held in the Wheaton College Dining Hall of Wheaton College, Wheaton, Illinois on Saturday morning, April 28, 1962, with President John C. Frye presiding. Thirteen persons were present.

Dr. G. R. Yohe, Secretary pro-tem, reported that 298 persons had registered for the 55th Annual Meeting; 190 of these were Academy members. The report on the Section meetings showed that all twelve had met on April 27, 1962; that 116 papers were presented, six were read "by title," and that the total of maximum figures reported by the Section Chairmen was 404.

The Educational Films Evaluation Committee was reappointed as it stood last year except for the addition of Mr. Matthew Prastein.

The Junior Academy Re-evaluation Committee was re-established for the coming year.

Dr. G. R. Yohe was appointed Chairman of the Nominations Committee. It was pointed out that there were advantages to appointing this Committee very early.

The Planning Committee was continued for this year and the Council recommended that it be approved as a Standing Committee at the next annual business meeting.

Dr. Wesley J. Birge was reappointed Editor of the TRANSACTIONS and the present Editorial Board was continued.

Dr. Wm. M. Lewis was appointed Chairman of the Audit Committee.

Mr. Arthur R. Wildhagen was reappointed as the Academy's Publicity Advisor.

The Chairman of the Budget Committee was advised that his report should be made at the November Council meeting.

Dr. W. D. Klimstra was made Trustee of the Frank Reed Memorial Fund.

Second Council Meeting. This was held in the Anniversary Room of the Hotel St. Nicholas in Springfield on Saturday, November 24, 1962. Eight members of the Council were present, as well as nineteen Committee and Section Chairmen and some 30 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.

The Treasurer was authorized to make investments up to $3500.00 at his discretion.

President Frye appointed an Ad Hoc Committee to study the problem of charges made to libraries for the transactions and the handling of such monies.

Dr. Joseph R. Caldwell, Chairman, Committee on Archaeological and Historical Sites reported that the State of Illinois will purchase some 80 additional acres of the Great Cahokia Site.

Dr. S. E. Harris presented the report of the Budget Committee.

Third Council Meeting. This was held in the Illini Union Building, Urbana, Illinois on Saturday, February 23, 1963. Eight Council members were present, and eight Section Chairmen were present. Thirty officers and guests of the Junior Academy were also present.

The Treasurer's report was presented and accepted.

Dr. Klimstra reported that the Academy membership was: 46 Sustaining and Patron members, 859 regular members, and 7 library members.

Dr. E. H. Hadley, Second Vice-President, reported that all physical facilities at Southern Illinois University have been reserved for the 56th Annual Meeting.

Mr. Milton Thompson, Librarian, presented his report. Arrangements have been made with the Treasurer to receive an up-to-date membership list to remove the discrepancies from his mailing list.

Mr. Thompson recommended the Volume 55 be terminated with the Number 2 issne and begin Volume 56 with the papers that were planned for the Number 3 issue of Volume 55.

Dr. W. D. Klimstra, Chairman, Ad Hoc Committee on the Academy Transactions presented the following recommendations which were approved by the Council:

1. All libraries should purchase the Transactions rather than receiving it free, and that the rate be $6.00 per Volume for those in the United States and $6.50 per Volume for those in foreign countries.
2. Exchange arrangements be one which involves agencies similar in nature to the Academy.
3. Materials received by the Academy Librarian in exchange for Transactions be examined, and those for which the Museum has no use, be presented to the Library of an appropriate liberal arts college in Illinois.
4. For all Transactions 1957 back through the earliest issues, a charge of $2.50 per volume and from 1958 on, the charge will be $1.50 per issue.

Dr. E. C. Galbreath, Southern Illinois University, was appointed Editor of the Transactions.

The Secretary was instructed to prepare and submit to the membership for action at the 56th Annual Meeting the following amendments to the constitution and By-Laws which would provide for the following:

1. The student membership category should apply to graduate students as well as undergraduate students.
2. Establish a new membership category, Emeritus membership. This would be open to those persons who are retired from their professional duties, on permanent sick leave, or other such unavoidable types of discontinuance of their profession. The annual dues for Emeritus membership shall be $1.00.
3. Provide for presenting the budget at the November meeting of the Council.

The Secretary read a letter from Dr. Lloyd M. Bertholf, President, Illinois Wesleyan University, Bloomington, Illinois, inviting the Illinois State Academy of Science to hold their Annual Meeting on their campus in 1964. The invitation was accepted by the Council.

Fourth Council Meeting. This meeting was called to order at 7:30 P.M. by President John C. Frye following a dinner in the Missouri Room, Memorial Center, Southern Illinois University, Carbondale, Illinois on April 25, 1963. Twelve Council members, three Section Chairmen, an dseven other officers and Committee Chairmen were present.

The following motion regarding the operation of the Junior Academy of Science was passed by the Council:

"In order to facilitate efficient operation of the Junior Academy, which now operates as a function of the Illinois State Academy of Science and under the control of the Council (Constitution article VIII — Junior Academy), the council directs that as soon as practicable, and in any event within a year from the date of this action the Junior Academy shall reorganize its state office in accordance with the following provisions.

As provided in the Constitution there shall be a general chairman and a general chairman-elect, elected by the members of the Academy at its annual meeting. There shall be created, as an advisory body to the general chairman a Junior Academy Steering Committee, consisting of 5 members and the general chairman and general chairman-elect, ex-officio. The members of the Steering Committee must be elected from the membership of the Illinois State Academy of Science by the Council of the Academy. District Chairmen, as well as the general chairmen, are encouraged to submit nominations to the Academy Council for election to the Steering Committee. The Steering Committee shall elect from its members its own chairman, a secretary and a treasurer of the Junior Academy.

The Junior Academy Secretary shall record minutes of the meetings of the Steering Committee, and shall transmit copies of such minutes to the Secretary of the Academy; he shall also perform such duties pertaining to the office as the Steering Committee may require.

The Junior Academy Treasurer shall be responsible for handling all funds of the Junior Academy and shall report to the Junior Academy Steering Committee; he shall be responsible for preparing the appropriate reports for the Internal Revenue

Service and the Academys' Auditing Committee.

It is the desire of the Council that financial support from the Illinois State Academy of Science to the Junior Academy be in the form of a grant each year. The amount to be determined by the Council, and paid by the Academy Treasurer to the Treasurer of the Junior Academy." Dr. W. D. Klimstra, Treasurer reported that there are presently 936 paid members.

Mr. Milton Thompson, Librarian, reported that Volume 54, Numbers 3 and 4 and Volume 55, Number 1 of the Transactions have been printed. Volume 55, Number 2 and Numbers 3 and 4 are in print and Volume 56, Number 1 has been submitted to the printer.

It was reported that the proposed changes in the Constitution had not been mailed to the membership twenty (20) days prior to the annual meeting as is required by the Constitution. Therefore, the membership cannot legally act on these proposed changes at the 56th Annual Business Meeting.

The 56th Annual Meetings

Genenal Meeting. The general session of Friday morning, April 26, 1963, held in the Morris Library Auditorium, Southern Illinois University, Carbondale, Illinois was called to order by President John C. Frye at 10:00 A.M.

Dr. William McKeefrey, Dean of Academic Affairs, Southern Illinois University, gave the address of welcome. This was followed by Dr. Frye's Presidential address, "Development of the Bedrock Surface of Illinois."

Section Meetings. On Friday afternoon, April 26, the following papers were presented:

ANTHROPOLOGY

Room 306, Home Economics
Morris Freilich, Chairman
Northern Illinois University

- 1:30 Current Approaches to Human Ecology. Demetri B. Shimkin.
- 1:50 Saskatchewan Cultural Ecological Research. John W. Bennett.
- 2:10 Tethered Nomadism and Water Territoriality: A Hypothesis. Walter W. Taylor, Southern Illinois University, Carbondale.
- 2:30 Ecological Adaptations: A Study of Technological and Social Variables Among the Kofyar of Northern Nigeria. Robert M. Netting.
- 2:50 Folk Medicine in Village and Indian Mexico. Carroll L. Riley.
- 3:10 An Ecological Reconstruction of the Cahokia Area. Harold P. Jenson.
- 3:30 The Role of the Uplands in Illinois State History. James A. Brown.
- 3:50 Election of Chairman for 1964.

AQUATIC BIOLOGY

Room 144, Agriculture
Leo F. Rock, Chairman
Illinois Department of Conservation
Sterling

- 1:30 Time of Feeding of the Bluegill and Green Sunfish. David B. Crandall and Hurst H. Shoemaker, University of Illinois, Urbana.
- 1:50 What is Happening to the Protected and Unprotected Game Fish in Reelfoot Lake, Tennessee? Robert J. Schoffman, Spalding Institute, Peoria.
- 2:10 Some Observations on the Biology of the Buffalofishes in the Illinois River. William C. Starrett, Illinois Natural History Survey, Havana.
- 2:30 Aquatic Use of Endothall Formulations. Harold L. Lindaberry and Frederick E. Temby, Pennsalt Chemicals Corporation, Aurora.
- 2:50 Rehabilitation of the Fish Population on Two State Conservation Lakes. A. C. Lopinot, Illinois Department of Conservation, Springfield.
- 3:10 Election of Chairman for 1964.
- 3:30 Summary Report of the Little Wabash River Drainage Basin. Raymond Fisher, Illinois Department of Conservation, Fairfield.
- 3:50 The Use of Rotenone on City Water Supply Lakes in Illinois to Control Undesirable Fish Populations. James L. La Buy, Illinois Department of Conservation, Macomb.
- 4:10 The Fish Population in Weldon Springs Lake. Rudolph Stinauer, Illinois Department of Conservation, Havana.

BOTANY

Section A
Room 205, Life Science
Frank A. Crane, Chairman
College of Pharmacy,
University of Illinois, Chicago

1:30 Differential Effects of Phosphate Supply Upon Growth in Sorghum Mutant Greenstripe; 1 (gs_1) vs. Texas Blackhull Kafir. K. H. Harmet, Northern Illinois University, DeKalb.

1:45 Unusual Symptoms of Inorganic Nutrient Deficiency in Peppermint. F. A. Crane, University of Illinois, College of Pharmacy, Chicago.

2:00 Effect of Spacing on the Specific Gravity of Plantation-grown Loblolly Pine in Southern Illinois. W. A. Geyer, University of Illinois, Urbana.

2:15 Continuous Stem Growth of Loblolly Pine and its Dependency Upon Translocated Growth Substances. A. R. Gilmore, University of Illinois, Dixon Springs Expt. Sta., Robbs.

2:30 Temperature Effects on Germination and Root Growth in Afterripened and Non-afterripened Peach Seedlings. R. Kupelian, University of Chicago, Chicago.

2:45 The effects of Various Factors on Seed Germination of *Geum turbinatum*, on Alpine Plant. G. F. Spomer, University of Chicago, Chicago.

3:00 Election of Chairman for 1964 (Sections A and B convene here).

3:15 Consistent Abnormalities in the Psilotum Fertile Shoot. A. S. Rouffa, University of Illinois, Navy Pier, Chicago.

3:30 Changes in the Composition of Brownfield Woods since 1925. W. R. Boggess, University of Illinois, Urbana.

3:45 Variability of Dormant Season Temperature in Illinois. J. B. Mowry, Illinois Hort. Expt. Station, Carbondale.

4:00 Vegetation — Soil Relationship in Hill Prairies. D. K. Warren and P. D. Kilburn, Principia College, Elsah.

Section B
Room 323, Life Science
Barbara Palser, Presiding
University of Chicago, Chicago

1:30 *Conostoma kestospermum*, A New Species of Paleozoic Seed from the Middle Pennsylvanian. T. N. Taylor, University of Illinois, Urbana.

1:45 Organography and Vascular Anatomy of the Flower in the Salaxidae. Y. S. Murty and Barbara Palser, University of Chicago, Chicago.

2:00 The developmental anatomy and relationship of the Ranales. A. Hayat, Loyola University, Chicago.

2:15 Some observations on Embryology in *Kalmia*. P. S. Ganapathy, University of Chicago, Chicago.

2:30 A Hexaploid *Allium* sp. cultivated as Garlic in Southern Illinois. L. V. Olah and Jane A. Hinners, Southern Illinois University, Carbondale.

2:45 Observation on the Zoospores and Young Colonies of *Pediastrum boryanum*. J. S. Davis, Southern Illinois University, Edwardsville.

3:00 Election of Chairman for 1964 (Sections A and B convene here.)

3:15 Genetic Control of Conidiation in *Aspergillus rugulosis*. D. O. Coy and R. W. Tuverson, University of Chicago, Chicago.

3:30 Fungi Associated with the Sporangia of Species of Myxomycetes. Judith K. Rippy, Marjorie Christiansen, and J. C. Gilman, Southern Illinois University, Carbondale and Iowa State University.

3:45 A preliminary Checklist of Fleshy Fungi from Jackson and Union Counties. Martha M. Bankson and J. C. Gilman, Southern Illinois University, Carbondale.

4:00 Fungel Population from Early Stages of Succession in Indiana Dune Sands. Wohlrab, Gisela, University of Chicago, Chicago.

CHEMISTRY

Section A

Room 111, Parkinson Laboratory
Robert E. Van Atta, Chairman
Southern Illinois University,
Carbondale

1:30 Election of Chairman-Elect for 1964 (Sections A and B convene here).
1:50 The Catalyzed Decomposition of $KClO_3$. R. F. Trimble, Southern Illinois University, Carbondale.
2:05 Infrared Studies of Metal Complexes of Amino Acids. Sister Mary Marina, B.V.M., Mundelein College, Chicago.
2:25 Spectrophotometric Determination of Activity Coefficients of Electrolyte Solutions. David G. Rands and A. J. Mogenis, Edwardsville Campus, Southern Illinois University, East St. Louis.
2:40 Absorption Studies of Stearic Acid and Several Low Molecular Weight Polymers on Chromium. Richard J. Ruch, Southern Illinois University, Carbondale.
2:55 Synthethis and Properties of Some Meta-Oxazines. Carl Weatherbee, Peter Han, Linda Provow, and Robert Wing, Milikin University, Decatur.
3:15 Recess (10 minutes).
3:25 Hydrogen Bonding Between Some Substituted Phenols and N,N-Dimethylacetamide. Melvin D. Joesten, Southern Illinois University, Carbondale.
3:40 Thermistors as Liquid-Solid Chromatographic Detectors. David J. Roth and D. E. Sellers, Southern Illinois University, Carbondale.
4:00 Cyclic Carbonates and Thiocarbonates. Carl R. Meloy, University of Illinois, Navy Pier, Chicago.
4:20 A Descriptive Coding System for Infrared Spectra. Robert E. Van Atta and Richard A. Persons, Southern Illinois University, Carbondale.
4:35 Adjournment.

Section B

Room 204, Parkinson Laboratory
Southern Illinois University,
Carbondale

1:30 Election of Chairman-Elect for 1964 (Convene with Section A).
1:50 Colloidal Properties of Gum Melia Azadirachta (Neem). R. S. Rai, Washington University, St. Louis, Missouri.
2:05 Wetting of Mixed Films of Fatty Acids with Hexadecane. Richard J. Ruch, Southern Illinois University, Carbondale.
2:25 The Infrared Spectra of Some Urea and Substituted Urea Coordination Compounds. Sister Mary Martinette, B.V.M., Mundelein College, Chicago.
2:40 Synthesis of 1,2-Diazetidineones. Herbert Hall, Southern Illinois University, Carbondale.
2:55 Solubility of Barium Monofluorophosphate. David G. Rands and Roy E. Bruns, Edwardsville Campus, Southern Illinois University, East St. Louis.
3:15 Recess (10 minutes).
3:25 Compounds of Inert Gases. R. F. Trimble, Southern Illinois University, Carbondale.
3:40 The Effect of Gamma Radiation on A.T.P., Lysozyme, and A.T.-P.-Lysozyme Complex. Frank O. Green, Wheaton College, Wheaton.
4:10 The Reactions of Olefins with N-Bromosulfonamides. Edward R. Newman and William J. Probst, Edwardsville Campus, Southern Illinois University, East St. Louis.
4:25 Iodine-Dimethyl Sulfoxide Reaction. Rebecca Reid and Boris Musulin, Southern Illinois Unisity, Carbondale.
4:35 Adjournment.

CONSERVATION

Room 154, Agriculture
Donald T. Ries, Chairman
Illinois State Normal University

1:30 Disappearance of Hill Prairies Through Forest Encroachment. Paul Kilburn, Principia College.
1:45 Ecosystem Studies of Strip Mine Forest Plantings. M. B. Baker, Jr. and W. C. Ashby, Southern Illinois University, Carbondale.
2:00 Experimental Leptospririosis in the Deer Mouse. Deam H. Ferris, University of Illinois, Urbana.
2:10 The Vanishing Prairie Chicken. Hurst H. Shoemaker, University of Illinois, Urbana.
2:40 Election of Chairman for 1964.

GEOGRAPHY

Room 168, Agriculture
Stanley Shuman, Chairman
Illinois State Normal University

1:30 The Network of Inland Waterways in England. J. Allan Patmore, Southern Illinois University.
1:45 The Valley of Comacchio: An Italian Zuider Zee. David L. Wheeler, Illinois State Normal University, Normal.
2:00 Environmental Factors Involved in Studying the Relationship Between Soil Elements and Disease, with an Iceland Example. R. W. Armstrong, University of Illinois, Urbana.
2:15 Prospects for the Panama Canal. David J. Fox, Southern Illinois University, Carbondale.
2:35 African Population Patterns. Elsa Schmidt, Illinois State Normal University, Normal.
2:55 Philippine Mineral Production. Alden Cutshall, University of Illinois, Chicago.
3:10 Election of Chairman for 1964.
3:30 Depression and Agricultural Change in Southern Illinois, 1880-1900. Kevin R. Cox, University of Illinois, Urbana.
3:50 The Amish Community of Illinois—A Cultural Island. Dalias A. Price, Eastern Illinois University, Charleston.
4:00 The Old Order Amish Community of Arthur, Illinois. Lois Fleming, Harvey.
4:10 The Socio-Economic Spatial Structure of Illinois. John Allman, Kevin Cox, Rainer Erhart, and Lorne Russwurn, University of Illinois, Urbana.
4:25 The Concept of Shape in Geography. Ronald R. Boyce and W. A. V. Clark, University of Illinois, Urbana.

GEOLOGY

Room 216, Agriculture
R. L. Langenheim, Jr., Chairman
University of Illinois, Urbana

1:30 Some Highlights in the History of the Illinois Geological Survey. M. M. Leighton, Illinois State Geological Survey, Urbana.
2:00 Early Pennsylvanian Faunas of the Illinois Basin. M. L. Thompson and R. H. Shaver, Illinois State Geological Survey and Indiana Geological Survey.
2:30 Origin of Stromatactis Cavities in the Silurian Reefs of Northern Indiana. A. V. Carozzi and D. A. Textoris, University of Illinois, Urbana.
2:50 Stratigraphy of the Lake Lahontan Deposits in the Winnemucca Area, Nevada. Keros Cartwright, Illinois State Geological Survey, Urbana.
3:10 Election of Chairman for 1964.
3:30 Geomorphology of Pine Hills, Union County, Illinois. S. E. Harris, Southern Illinois University, Carbondale.
3:50 Bedrock Geology of Parts of the Gorham Area. F. R. Pickard, Southern Illinois University, Carbondale.
4:15 Experimental Replacement of Oolitic Limestone by Fluorite. J. W. Baxter, Illinois State Geological Survey, Urbana.
4:30 A Silurian Reef. R. H. Howard, Illinois State Geological Survey-Wapella East Oil Pool, De Witt County, Illinois.

METEOROLOGY and CLIMATOLOGY

Room 222, Agriculture
James E. Carson, Chairman
Argonne National Laboratory, Argonne

1:30 The Effect of Organic Compounds on the Reduction of Water Losses from Soils. J. P. Vavra and W. J. Roberts, Southern Illinois University, Carbondale and State Water Survey Division, Urbana.
1:55 Special Aerial Cloud Observations as an Aid to a Study of Cloud Systems Associated with Developing Cyclones. Dorothy L. Bradbury, University of Chicago, Chicago.
2:20 Project "Whitetop"—A Field Experiment in the Physics of Precipitation. Edward L. Harrington, University of Chicago, Chicago.
2:50 Election of Chairman for 1964.
3:15 Range of Evapotranspiration in Illinois. Douglas M. A. Jones, Illinois State Water Survey, Champaign.
3:35 Precipitation in a 550-Square-Mile Area of Southern Illinois.

Stanley A. Chagnon, Jr., Illinois State Water Survey, Urbana.

4:00 Air Monitoring Program in Chicago. Samuel G. Booras, Department of Air Pollution Control, Chicago.

4:25 The Importance of Satellite Radiation Measurements to Long-Range Forecasting. Grant L. Darkow, University of Missouri, Columbia, Missouri.

MICROBIOLOGY SECTION

Room 308, Parkinson
Leslie R. Hedrick, Chairman
Illinois Institute of Technology, Chicago

1:30 Mutation at the Melezitose Locus in Saccharomyces. Donna Hwang and Carl Lindegren, Southern Illinois University, Carbondale.

1:45 Detection of Anonymous Mycobacteria in a Public Health Laboratory. Nathan Nagle, Dept. of Public Health, State of Illinois, Carbondale.

2:00 The Mode of Action of Microwaves (2450 mc) on Bacterial Endospores. Nick Grecz, Radiation Laboratory, Food & Container Institute Armed Forces Laboratory, Chicago.

2:15 Biochemical Changes During Growth of *Penicillium atrovenetum*. James Van Etten and David Gottlieb, Department of Plant Pathology, University of Illinois, Urbana.

2:30 Influence of Seed Irradiation on the Growth Rate of Carrot Plants. H. H. Thornberry and Inez N. Kamp, Department of Plant Pathology, University of Illinois, Urbana.

2:45 Growth of *Acanthamoeba castellani* with the Yeast *Torulopsis famata*. L. C. Nero, Mae Goodwin-Tarver and L. R. Hedrick, Biology Department, Illinois Institute of Technology, Chicago.

3:00 Election of Chairman for 1964.

3:20 Filterability of Ampelamus Virus. R. E. Ellis and H. H. Thornberry, Dept. of Plant Pathology, University of Illinois, Urbana.

3:35 Electron Microscopy of Preparations Containing Ampelamus Virus. Mary R. Phillippe, R. E. Ellis, R. Borasky, and H. H. Thornberry, Dept. of Plant Pathology, University of Illinois, Urbana and Electron Microscope Laboratory, University of Illinois, Urbana.

3:50 Glucose Oxidation by Whole-Cells and Cell-Free Extracts of Fungi. Floyd M. Huber and David Gottlieb, Department of Plant Pathology, University of Illinois, Urbana.

4:05 Persistence of Potential Pathogens in the Respiratory Tracts of Normal Individuals. Isabell Havens, S.M., M.T. (ASCP), and R. S. Benham, Ph.D., Department of Medicine, University of Chicago, Chicago.

4:20 The Fluorescent Antibody Procedure in a Public Health Laboratory. Nathan Nagle, Department of Public Health, State of Illinois, Carbondale.

4:35 Effect of Cations upon Detection of Hydrophobicity of Yeast Cells Grown in Amino Acids. C. F. Feren and L. R. Hedrick, Biology Department, Illinois Institute of Technology, Chicago.

PHYSICS

Section A
Room 201, Main
Howard H. Claassen, Chairman
Wheaton College, Wheaton

1:30 Perennial Determination of Heavy Primary Cosmic Ray Flux at Geomagnetic Latitude of 41° N. O. B. Young and J. W. Lieh, Southern Illinois University, Carbondale.

1:45 Comparison of Cosmic Ray Star and Prong Counts of Two Canadian Balloon Flights of August 1957, One Before a Large Solar Flare and the Other Soon Afterward. O. B. Young, A. S. James and J. S. Rno, Southern Illinois University, Carbondale.

2:05 Use of an Analog Computer to Sum Multiple Fields of Radiation. Stanley D. Savic, sponsored by Lester S. Skaggs, Argonne Cancer Research Hospital, Chicago.

2:25 Automation of Physical Experiments. J. W. Butler, Argonne National Laboratory, Argonne.

2:45 Electrical Properties of Indium Oxide (In^2O_3). Waldon B. Roush, Southern Illinois University, Carbondale.

3:00 Election of Chairman for 1964.
3:15 Effective Young's Modulus of Anisotrophic Polycrystals. William C. Shaw, Southern Illinois University, Southwestern Illinois Campus, East St. Louis.
3:30 Compton Reduction by Sum-Coincidence Method. Harold D. Belt, Southern Illinois University, Carbondale.
3:50 Growth of Crystals by Coevaporation in a Vacuum. Ralph J. Miller, Otis Wolkins, Hugh Siefken and John Hunt, Greenville College, Greenville.
4:10 The First Order Phase Change of MnBi. Thomas A. Reed, University of Illinois, Urbana.

Section B
Room 206, Main

1:30 Potential Function Using Elliptic Functions. Boris Musulin, Southern Illinois University, Carbondale.
1:45 Pion Life-Time and the 8-Fold Symmetry. Dan J. Welling, Southern Illinois University, East St. Louis.
2:00 An Approach to Special Functions of Quantum Mechanics. Richard B. Watson, Southern Illinois University, Carbondale.
2:20 Nuclear Magnetic Resonance in Ferromagnetic Nickel. T. J. Rowland, University of Illinois, Urbana.
2:40 Calculation of the Entropy of Gaseous Nitrogen and Argon from a Molecular Model Using Classical Physical Methods. Harry H. Hull, 18529 Lyn Court, Homewood, Illinois.
3:00 Election of Chairman for 1964 (Convene with Section A).
3:15 Physical Principles and the Laboratory Arts. Howard C. Roberts, University of Illinois, Urbana.
3:30 Why Things Fall. William H. Kane, O.P., Aquinas Institute of Philosophy, River Forest.
3:45 Dr. Mahlon Loomis, American Discoverer of Radio, 1865. O. B. Young, Southern Illinois University, Carbondale.

SCIENCE TEACHING

Room 102, Main
Otto Ohmart, Chairman
Anna, Illinois

1:30 The Philosophy of Science: A College Freshman Course. George Kimball Plochmann, Southern Illinois University, Carbondale.
1:50 Teaching of Physical Science in the Elementary School. Calvin P. Midgley, Mundelein College, Chicago.
2:10 Quantitative Aspect of Simple Experiments. John R. Carlock and Harold A. Moore, Illinois State Normal University, Normal.
2:30 Biology Teaching at Illinois State Normal University—1857-1930. Robert H. Satterfield, Illinois State Normal University, Normal.
2:50 Science Teaching as a Continuing Interest of the Illinois State Academy of Science. Walter B. Hendrickson, MacMurray College, Jacksonville.
3:10 Election of Chairman for 1964.

ZOOLOGY

Room 224, Agriculture
Jack Bennett, Chairman
Northern Illinois University

1:30 Breeding Bird Populations of Busey Woods, Urbana, Illinois. 1962. Lois Haertel, University of Illinois, Urbana.
1:45 Age Determination of the Greater Prairie Chicken *Tympanuchus cupido pinnatus* as Determined by Juvenile Feather Replacement. Stanley Etter, University of Illinois, Urbana.
2:00 Experimental Studies with the Laysan Albatross on Midway Atoll, Pacific. Harvey I. Fisher, Southern Illinois University, Carbondale.
2:15 Relationship of Blood Type and Some Behavioral Characteristics in the Chicken. Karen Hagen and Jack Bennett, Northern Illinois University, DeKalb.
2:30 Low Frequency Sound Discrimination in the Roach (*Periplaneta americana*). Donald M. Miller and John D. Anderson, University of Illinois, Urbana.
2:45 Clinical and Laboratory Evaluation of Pain. Murray M. Hoffman, Northwest Hospital, Chicago.
3:15 Election of Chairman for 1964.
3:30 Bot Reared from House Mouse. Garland T. Riegel, Eastern Illinois University, Charleston.
3:45 Sulfydryl Compounds and Genet-

ic Effects of Radiation. Sidney Mittler, Northern Illinois University, DeKalb.

4:00 The Effect of AET on Radiation Induced Sex-linked Recessive Mutations in *Drosophila melanogaster*. Arnold Hampel and Sidney Mittler, Northern Illinois University, DeKalb.

4:15 Uptake and Tissue Distribution of 3-methylcholanthrene-6-C^{14} in the Sprague-Dawley Female Rat. William B. Horner, Knox College, Galesburg.

THE ANNUAL BUSINESS MEETING

The Business Meeting was called to order at 5:00 P.M., April 26, 1963, in the Morris Library Auditorium, Southern Illinois University, Carbondale, Illinois, by President John C. Frye. About 65 members were in attendance.

Reports of Officers

Secretary Paloumpis reported items which are recorded in the foregoing reports of the 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. Kaplan.

Librarian Thompson's report was presented.

Reports of Standing Committees

Dr. Kaplan (Animal Experimentation in Research) reported that the Committee is cooperating with the Illinois Society for Medical Research on the essay contest which is open to high school students.

The following report was submitted by Dr. Van Lente, Chairman of the Research Grants Committee:

The Research Grants Committee recommends that the following grants be awarded:

Dr. Dale E. Birkenholz—$150.00
Illinois State Normal University
Necropsy Study on Bats

Dr. Howard R. Hetzel—$100.00
Illinois State Normal University
Composition and Function of Cellular Elements in Body Fluids of Holothurians and Other Echinoderms

Dr. Robert D. Weigel—$53.00
Illinois State Normal University
Research on Fossil Birds

Sister Mary Marina—$150.00
Mundelein College
Metal Complexes of Amino Acids

Dr. Robert H. Mohlenbrock—$150.00
Southern Illinois University
The Cyperaceae of Illinois

Dr. Robert E. Van Atta—$111.00
Southern Illinois University
Construction and Use of a Modified High Frequency Titrimeter

Dr. Ross F. Shaw—$150.00
Greenville College
Physiological Properties of Strains of *Tetrahymena vorax*

A motion for the approval of these grants was made by Dr. Van Lente, seconded by Dr. Kaplan, and was passed.

Reports of Special Committees

The Resolutions Committee (Dr. C. L. Kanatzar, Chairman) 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 Southern Illinois University have provided the arrangements for this Fifty-Sixth Annual Meeting of the Illinois State Academy of Science,

Be it resolved that the Academy express its gratitude to all who have served in any capacity in promoting the welfare of the members during this meeting, and especially to

Dr. Delyte W. Morris, President of the University

Dr. Elbert H. Hadley, Second Vice President of the Academy in charge of local arrangements,

Dr. Benson B. Poirier, Assistant Dean of Extension, and The Extension Division of Southern Illinois University.

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 Geology and Botany of Southern Illinois University, Dr. Stanley E. Harris, and Dr. Clark Ashby have accepted the responsibility for sponsoring the Field Trip to the Pine Hills Experimental Station as a significant portion of the program for the Fifty-sixth Annual Meeting of the Academy,

Be it resolved that the Academy expresses its thanks to those responsible for organizing and conducting this Field Trip.

Be it further resolved that the Secretary be directed to send copies of this resolution to those specifically named.

3. APPRECIATION OF SERVICE

Whereas Mr. Donald G. Hopkins has served the Academy in a diligent and productive manner as General Chairman of the Illinois Junior Academy of Science for the past two years,

Be it resolved that the members of the Academy express their appreciation for his service, and that the Secretary be directed to send him a letter of commendation.

4. NECROLOGY

Whereas the Academy has lost by death within the past year the following members:
Ira Oliver Nothstein
Annie L. Weller
Brady P. Maddox

Be it resolved that the members of the Academy express their sorrow by rising for a moment of silence.

New Business

President Frye announced that the proposed amendments to the Constitution could not be acted upon at this years business meeting because the proposed amendments did not reach the membership twenty days prior to the meeting, as is specified in the Constitution. Therefore, the proposed amendments will be acted upon at the next annual meeting.

The Secretary read the following proposed By-Law changes:

1. By-Law II-6: "The budget committee shall submit at the second Council meeting for its consideration and review a budget of anticipated income and recommended expenditures for the following year." Mr. Thompson moved that the proposed change be adopted. The motion was seconded by Dr. Klimstra and was passed.
2. By-Law V-1: "A Historian shall be appointed by the Council annually at its first meeting. His duties shall be the usual ones pertaining to that office." Dr. Boewe moved that the proposed By-Law be adopted. The motion was seconded by Mr. Schoffman and was passed.

The report of the Nominating Committee was read by Dr. Yohe, Chairman. Dr. Yohe moved and Mr. Bamber seconded that the report be received. Carried. Mr. Bruce Campbell moved that a unanimous ballot be cast 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. The motion was seconded by Dr. Kaplan, and those present rose to their feet.

The meeting was adjourned at 6:00 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.

February 23, 1963

ILLINOIS STATE ACADEMY OF SCIENCE

TREASURER'S ANNUAL REPORT

JANUARY 1, 1962—DECEMBER 31, 1962

BALANCE CARRIED FORWARD, January 1, 1962			$ 22,096.37
TOTAL RECEIPTS			
Dues			
Regular		$ 7,428.83	
Sustaining & Patron		3,995.00	
Registration		142.50	
AAAS Research Grants		864.00	
Interest, U. S. Bonds		91.70	
Interest, Savings & Loan Assoc.		135.00	
Refunds from Districts		107.37	
Sale of Publications		1.54	
Refund of Overpayment		3.97	
NSF 17016		7,500.00	
Jr. Academy School Registrations		2,716.50	
			$ 22,968.41
			$ 45,082.78
TOTAL EXPENDITURES			
Regular Academy			
Council		$ 123.57	
Secretary's Office		769.19	
Treasurer's Office		821.86	
Editor's Office		287.98	
Librarian		144.35	
AAS Research Grants		864.00	
Honoraria		350.00	
Membership Committee		58.10	
Sust. & Patron Membership Comm.		— —	
Planning Committee		— —	
Publications		— —	
State Savings & Loan		— —	
Miscellaneous		370.69	
Junior Academy			
General (1961-62)	$ 4,172.04		
S. T. S. (1961-62)	387.55	4,559.59	8,349.33
TOTAL			$ 8,349.33
NSF G-17016:			
Printing and Publications		$ 1,276.00	
District Expenses		4,800.00	
Secretarial		760.00	
Postage		405.50	
Stationery & Materials		160.10	
State Paper Sessions		404.87	
Travel		433.08	
Substitute Teacher		220.00	
Phone		257.00	
Judging		647.22	
Photography		121.25	
Univ. of Ill. Jr. Acad. Exposition		1,077.96	
TOTAL			$10,562.98

NSF G-17291:		
Travel & Subsistence	$ 6,776.17	
Honoraria	800.00	
Secretarial	301.55	
Supplies	359.83	
Field Trip Leader	284.00	
Other Expenses	59.72	
Refund (unexpended balance ret'd to NSF)	$ 4,646.39	
TOTAL		$13,227.66
Junior Academy of Science (July 1—December 31, 1962)		
State Chairman's Office		
Stenographic	$ 394.00	
Travel	84.34	
Hire of Substitute Teacher	24.00	
Postage	200.00	
Telephone & Telegraph	46.00	
Stationery & Materials	100.00	
		$ 848.34
Publications and Printing		
1962 Yearbook	$ 1,248.69	
Handbook	40.75	
Newsletters	150.00	
Pamphlets	52.50	
		$ 1,491.94
TOTAL		$ 2,340.28
Outstanding checks of 1961 cashed in 1962:		
Senior Academy	$ 140.28	
NSF G-17016	166.15	
NSF G-17291	91.95	
		$ 398.38
Outstanding checks for 1962:		
Senior Academy	$ 1.50	
NSF G-17291	31.50	
		$ 33.00
TOTAL ACTUAL EXPENDITURES		$ 34,845.63
Cash in Carbondale National Bank, December 31, 1962		$ 10,237.15
OTHER ASSETS		
Permanent Fund (U. S. Bonds)	$ 1,700.00	
		$ 1,700.00
Reserve Funds		
U. S. Bonds	1,800.00	
State Savings & Loan Assoc.	6,000.00	
		$ 7,800.00
Frank Reed Memorial Fund		
Balance carried forward Jan. 1, 1962	$ 886.43	
Contributed by Council	100.00	
Honorarium contributed by G. R. Yohe	150.00	
Interest	41.66	
		$ 1,178.09
TOTAL OTHER ASSETS		$10,678.09

Total Assets of Academy, December 31, 1962		
Cash in Carbondale National Bank	$10,237.15	
Total Other Assets	10,678.09	
		$20,915.24
Cash in Carbondale National Bank, December 31, 1962		
Balance in Jr. Acad. of Sci. Regist.	$ 376.28	
Outstanding checks	33.00	
Permanent Fund—Cash	250.00	
		$ 659.28
Total Uncommitted Cash, December 31, 1962		$ 9,577.87

Submitted by W. D. Klimstra, Treasurer

OFFICERS AND STANDING COMMITTEE NOMINEES FOR 1963-64 ILLINOIS STATE ACADEMY OF SCIENCE

PRESIDENT: Elnore Stoldt, 759 S. Church St., Jacksonville.
FIRST VICE PRESIDENT: Howard W. Gould, Northern Ill. Univ., DeKalb.
*SECOND VICE PRESIDENT: Joseph Collins, Ill. Wesleyan Univ., Bloomington.
SECRETARY: Andreas A. Paloumpis, Ill. State Univ., Normal.
TREASURER: Willard D. Klimstra, Southern Ill. Univ., Carbondale.
LIBRARIAN: Milton D. Thompson, Ill. State Museum, Springfield.
GENERAL CHAIRMAN, JUNIOR ACADEMY: William A. Hill, Naperville Comm. H.S., Naperville.

THE COUNCIL

IMMEDIATE PAST PRESIDENT: John C. Frye, State Geol. Surv., Urbana.
COUNCILORS: G. H. Boewe (to 1964), State Nat. Hist. Surv., Urbana.
Lyle E. Bamber (to 1965), 101 Burril Hall, Univ. of Illinois, Urbana.
Norman D. Levine (to 1966), 143 Vet. Med. Bldg., Univ. of Ill., Urbana.
Robert C. Wallace (to 1967), Reavis H. S., Oak Lawn.

OTHER OFFICERS

CHAIRMAN-ELECT, JUNIOR ACADEMY: Maurice G. Kellogg, Science Supervisor, Western Ill. Univ., Macomb.
*EDITOR: E. C. Galbreath, Southern Ill. Univ., Carbondale.
*PUBLICITY ADVISOR: Arthur R. Wildhagen, Univ. of Ill., Urbana.
*DELEGATE TO THE AAAS: Norman Levine, Univ. of Ill., Urbana.
*DELEGATE TO THE AAAS ACADEMY CONFERENCE: Joan Hunter, West Sr. High School, Aurora.
*HISTORIAN: Walter B. Hendrickson, MacMurray College, Jacksonville.

STANDING COMMITTEES

AFFILIATIONS: George E. Ekblaw, Chairman, State Geol. Survey, Urbana.
Thorne Deuel, Illinois State Museum, Springfield.
Elbert H. Hadley, Southern Illinois University, Carbondale.
Sidney Mittler, Northern Illinois University, DeKalb.

ANIMAL EXPERIMENTATION IN RESEARCH:
Harold Kaplan, Chairman, Southern Illinois University, Carbondale.
Garwood A. Braun, Highland Park High School, Highland Park.
N. R. Brewer, 951 East 58th Street, Chicago.
Robert Schoffman, Spalding Institute, Peoria.
F. R. Steggerda, University of Illinois, Urbana.

ARCHAEOLOGICAL AND HISTORICAL SITES:
Joseph Caldwell, Chairman, Illinois State Museum, Springfield.
Cecilia Peikert Bunney, Illinois State University, Normal.
William H. Farley, Box 433, Harrisburg.
Mary Grant, 805 Randolph, Oak Park.
B. G. Johnson, 1512 Quinton Road, S. E., Rockford.
John Mark McCleary, 2 Proviso West High School, Hillside.
James H. Sedgwick, 5922 N. Prospect Road, Peoria.
Daniel A. Throop, Call Printing Co., Third and Broadway, East St. Louis.

BUDGET: Stanley E. Harris, Chairman, Southern Ill. Univ., Carbondale.
Walter A. Brown, Illinois State Univ., Normal.
James H. Grosklags, Northern Illinois University, DeKalb.
Charles K. Hunt, Box 98, Hinsdale.
Carl Weatherbee, Millikin University, Decatur.

CONSERVATION: Willard D. Klimstra, Chairman, Southern Ill. Univ., Carbondale.
Stanley A. Changnon, State Water Survey, Urbana.
D. H. Ferris, University of Illinois, Urbana.
A. C. Foley, Box 336, Paris.
John C. Frye, State Geological Survey, Urbana.
Loring M. Jones, 513 Normal Road, DeKalb.
Paul D. Kilburn, Principia College, Elsah.
Herbert H. Ross, State Natural History Survey, Urbana.
Henry Sather, Western Illinois University, Macomb.

* Appointed by the President or by the Council.

LEGISLATION AND FINANCE: Wayne W. Wantland, Chairman, Ill. Wesleyan Univ., Bloomington.
John C. Frye, State Geological Survey, Urbana.
W. W. Grimm, Bradley University, Peoria.
Glenn H. Stout, State Water Survey, Urbana.
Loren P. Woods, Chicago Museum of Natural History, Chicago.

LOCAL CONVENTIONS: Elbert H. Hadley, Chairman, Southern Ill. Univ., Carbondale.
Fr. Robert R. Brinker (to 1964), St. James Trade School, Springfield.
Robert J. Smith (to 1965), Eastern Ill. University, Charleston.
Frank O. Green (to 1966), Wheaton College, Wheaton.
A. A. Paloumpis, *ex officio*, Illinois State University, Normal.

MEMBERSHIP: Max R. Matteson, Chairman, University of Ill., Urbana.
J. Bennett, Northern Illinois University, DeKalb.
Dorothy L. Bradbury, 5522 S. Cornell, Chicago 37.
Wesley Calef, University of Chicago, Chicago.
John C. Downey, Southern Illinois University, Carbondale.
D. Franzen, Illinois Wesleyan University, Bloomington.
Esther Griffith, Illinois State University, Normal.
John A. Harrison, State Geological Survey, Urbana.
Sister Mary Marina, B. V. M., Mundelein College, Chicago 26.
Russell L. Mixter, Wheaton College, Wheaton.
I. Edgar Odom, State Geological Survey, Urbana.
Herbert Priestley, Knox College, Galesburg.
Walter E. Parham, State Geological Survey, Urbana.
Charles D. Proctor, Loyola University, Chicago.
Yale S. Sedman, Western Illinois University, Macomb.
Ben T. Shawver, Monmouth College, Monmouth.
A. F. Silkett, University of Illinois, Navy Pier, Chicago.

RESEARCH GRANTS: Ralph J. Miller, Chairman, Greenville College, Greenville.
Eleanor Dilks, Illinois State University, Normal.
Mark Paulson, Bradley University, Peoria.
Charles Rohde, Northern Illinois University, DeKalb.
Fr. William J. Shonka, St. Procopius College, Lisle.
H. F. Thut, Eastern Illinois University, Charleston.
K. A. VanLente, Southern Illinois University, Carbondale.

SCIENCE TALENT: G. J. Froehlich, Chairman, University of Illinois, Urbana.
Hal F. Fruth, 5032 W. Morse, Skokie.
Leland Harris, Knox College, Galesburg.
Charles K. Hunt, Box 98, Hinsdale.
Herbert Priestley, Knox College, Galesburg.
Donald P. Rogers, University of Illinois, Urbana.
John D. Roslansky, University of Illinois, Urbana.

SUSTAINING MEMBERSHIP: C. Leplie Kanatzar, Chairman, MacMurray College, Jacksonville.
George R. Abraham, Lincoln-Way Community High School, New Lenox.
Robert A. Evers, State Natural History Survey, Urbana.
Wilbur W. Grimm, Bradley University, Peoria.
Milton Thompson, Illinois State Museum, Springfield.
Walter B. Welch, Southern Illinois University, Carbondale.

TEACHER TRAINING: R. Maurice Myers, Chairman, Western Ill. Univ., Macomb.
Lloyd L. Arnold, 5134 S. Harper Ave., Chicago 15.
E. R. Erickson, Augustana College, Rock Island.
Herbert F. Lamp, Chicago Teachers College, Chicago 21.
John A. Laverty, 8246 S. May Street, Chicago 20.
Wallace Miner, Northern Illinois University, DeKalb.
Gordon N. Murray, 1016 Harvard Terrace, Evanston.
John R. Samlin, LaSalle-Peru High School & Jr. Coll., LaSalle.
Sister Mary Martinette, B. V. M., Mundelein College, Chicago 26.
Sister M. Joan Preising, College of St. Francis, Joliet.
Robert C. Waddell, Eastern Illinois University, Charleston.

Special Committees

(All appointed by the President or by the Council)

AUDIT: William Lewis, Chairman, Southern Illinois University, Carbondale.
Boris Musulin, Southern Illinois University, Carbondale.

EDUCATIONAL FILMS EVALUATION COMMITTEE: Herman Eifert, Chairman, Illinois State Museum, Springfield.
Joseph Caldwell, Illinois State Museum, Springfield.
Melvin O. Foreman, Eastern Illinois University, Charleston.
Matthew Prastein, Illinois Wesleyan University, Bloomington.
James B. Sanders, Chicago Teachers College, Chicago.
Walter M. Scruggs, Eastern Illinois University, Charleston.
William Schwab, Office of Public Instruction, Springfield.

JUNIOR ACADEMY RE-EVALUATION COMMITTEE:
Representing the Academy
Robert A. Evers, Chairman, State Natural History Survey, Urbana.
Elaine A. Bluhm, University of Illinois, Urbana.
John C. Frye, State Geological Survey, Urbana.
C. Leplie Kanatzar, MacMurray College, Jacksonville.
Norman D. Levine, University of Illinois, Urbana.
Representing the Junior Academy
William A. Hill, Naperville Community High School, Naperville.
Donald G. Hopkins, Joliet Township High School & Jr. College, Joliet.
Sister Mary Ivo, B. V. M., Immaculata High School, Chicago.
Maurice G. Kellogg, Western Illinois University, Macomb.
Seichi Konzo, University of Illinois, Urbana.
Paul M. Wright, Wheaton College, Wheaton.

NOMINATIONS COMMITTEE: Kenneth Harmet, Chairman, Northern Ill. Univ., DeKalb.
W. C. Ashby, Southern Illinois University, Carbondale.
F. J. Kruidenier, University of Illinois, Urbana.
R. Maurice Myers, Western Illinois University, Macomb.

PLANNING COMMITTEE: Robert A. Evers, Chairman, State Natural History Survey, Urbana.
Kenneth E. Damann, Eastern Illinois University, Charleston.
E. C. Galbreath, Southern Illinois University, Carbondale.
John A. Harrison, State Geological Survey, Urbana.
Joan Hunter, West Senior High School, Aurora.
Norman D. Levine, University of Illinois, Urbana.
Ralph Miller, Greenville College, Greenville.
Kenneth A. VanLente, Southern Illinois University, Carbondale.
Carl Weatherbee, Milliken University, Decatur.

RESOLUTIONS COMMITTEE: C. Leplie Kanatzar, Chairman, MacMurray College, Jacksonville.
Gideon H. Boewe, State Natural History Survey, Urbana.
Harold M. Kaplan, Southern Illinois University, Carbondale.
Walter Scruggs, Eastern Illinois University, Charleston.

Section Chairmen

ANTHROPOLOGY: Dr. Charles H. Lange, Dept. of Anthropology, Southern Illinois University, Carbondale, Illinois.

AQUATIC BIOLOGY: Mr. Maurice Whitacre, Little Grassy State Fish Hatchery, RR No. 1, Carbondale, Illinois.

BOTANY: Dr. Kenneth Harmet, Northern Illinois University, DeKalb, Illinois.

CHEMISTRY: Dr. Bruce N. Campbell, MacMurray College, Jacksonville, Illinois.

CONSERVATION: Mr. Garwood Braun, Deerfield High School, Deerfield, Illinois.

GEOGRAPHY: Dr. Charles Alexander, Dept. of Geography, University of Illinois, Urbana, Illinois.

GEOLOGY: Dr. T. K. Searight, Dept. of Geography, Illinois State University, Normal, Illinois.

METEOROLOGY AND CLIMATOLOGY: Miss Dorothy L. Bradbury, Dept. of Geophysics, University of Chicago, Chicago 37, Illinois.

MICROBIOLOGY: Dr. K. C. Atwood, Dept. of Microbiology, University of Illinois, Urbana, Illinois.

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CONTENTS

THE PHILOSOPHY OF SCIENCE: A COLLEGE FRESHMAN COURSE

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This paper will discuss three questions: first, why philosophy of science should be taught at all in the freshman year at college; second, what is the most defensible way of giving such a course; and third, what one should expect from such a course.

I. The common reasons for introducing a course in the philosophy of science—that it acquaints the student with intellectual procedures common to all the scientific disciplines, that it helps to break up the too-close adherence to textbook pronouncements which may have been learned in high school, that it introduces a set of concepts broader than any one science and therefore not repeating familiar subject matter—are good enough to make tentative introduction worthwhile. But there are counter-reasons which must be met and disposed of: the course may encourage superficiality, it may be prematurely introduced, it may be unfair to those students who have had little science in high school.

There are two phases in teaching the philosophy of science. Early efforts to encourage habits of reflective thought about the concepts, principles, and proofs of science become a different sort of task *after* the student has acquired some familiarity with the data and procedures of science. This familiarity makes him aware, as a matter of course, that first of all science has some kind of method, and that the proposed premises and conclusions of a science command a respect which propositions of everyday colloquy do not, even though the scientific statements may repeatedly be brought into question. But a freshman who has had very little mathematics and perhaps no more of the other sciences than a short course in botany or zoology or one of the social studies, is in a poor position to commence evaluating scientific theories. A course in the philosophy of science for the beginner thus holds two sets of terrors for all but the most sophisticated of students: the need to master, at least in a rough way, the *materials* or contents of certain scientific arguments, and the need to grasp their *form*. The content is the science, the formal analysis is the philosophy. Later work, for more sophisticated students, could take for granted the content.

Science on the one hand has a peculiarity stemming from the very assumption that it is more than mere guesswork; a given scientific proposition sounds as if it were universally true for all instances falling under it. And there is a presumed necessity that a scientific proposition relates logically to other such propositions. To these two claims the student all too often responds by feeling that anything which passes for science is indisputably true, that one might as well unquestioningly accept it.

On the other hand, attempts to philosophize about the fallibility of our senses, about the intrusion of possible errors in our reasoning, or about the ambiguities of language employed in communicating results of scientific investigation almost invariably lead the student to the opposite attitude. He is now inclined to view the pursuit of solid truth as hopeless, and to fall back upon pragmatic expediency or upon the popular consensus as the standard for accepting or rejecting scientific statements. In brief, the study of science from a *scientific* viewpoint very easily leads to dogmatism. The *philosophic* study of science frequently results in skepticism. A superficial acquaintance with the history of scientific ideas suggests a vast confusion, with sets of interpretations of the universe succeeding each other dizzily. This may not be a grave disadvantage in the long run, because a dogmatic opinion must have its own antidote; but in the short run it bewilders the beginning student and apparently undoes precisely what teachers of science are trying to accomplish. Yet — here is the main point — the proper introduction of just such a questioning attitude will benefit not only students going on to major in philosophy, but also those who expect to become scientists. Reasons for this should become clear in the final section of this article.

So much for generalities. I now wish to attach this discussion to an experience of my own in the teaching of the philosophy of science, because such experience is not simply an artificial construction, and has many implications for us all.

II. Any elementary course in the theory of science must, I think, assume little prior familiarity with the facts of science and its long and fascinating history. For a number of years, from 1954 until the spring of 1962, I had responsibility for the teaching of a course which met approximately 24 hours during the term, had no prerequisites, accommodated about 50 students, and which was much restricted in the textbooks it could employ, owing to the confinements of a book rental system. On the other hand, perfect freedom in the style and content of the course was granted, and supplementary readings were frequently mimeographed as adjuncts to the texts, the first of these being *Treasury of Science* edited by Harlow Shapley and others, the second a more conventional anthology, *Philosophic Problems*, compiled by Mandelbaum, Gramlich, and Anderson. I used lectures and discussions, and where possible introduced simple demonstrations supplemented occasionally by slides and short motion pictures.

A course of this sort must retain a certain freshness of treatment. This means that at least part of its content must be changed each time that the material is run through. Moreover, events such as the orbiting of the first satellite, the death of Einstein, or the latest medical advance may make it profitable to give more than passing attention to the principles involved in contemporary scientific theories and technics. Here the teacher of the philosophy of science has a considerable advantage over that of one of the particular sciences, namely that he can quickly adapt any event to suit the context. The death of Einstein, for instance, could hardly be genuinely pertinent in a class in botany, or chemistry, but it could quickly be made relevant to any discussion of motion, time, space, the application of mathematics to nature, the steps in scientific method, the apparent discrepancies between sense data and intellectual interpretation, the theory of measurement, the problem of truth, the sociology of the spread of scientific ideas, the refutation of formerly prevailing doctrines. These are not ideas which attach to any one science exclusively; they fit, because of their philosophical nature, in all of the sciences, in many individual ways.

This very sort of consideration was instrumental in determining the structure and method of the course. In planning it, I made a list of three dozen or so concepts which seemed of most signal importance in the sciences and in the study of their methodologies. In making this list, it seemed wise to give preference to those concepts which, albeit changing their meaning while they did so, turned up in a plurality of sciences. Thus "circle" is important in geometry, but not in elementary arithmetic, and it enters the other sciences —where it does enter—chiefly as a geometrical notion applied literally. So "circle" was left off the list. But "color" is of interest in physics, in psychology, and in sociology (as regards fashions of preference). The readings from Newton and others, and the very simple demonstrations of color perception carried on with the help of felt patches and slides were used to show the ways in which the optical problem and the psycho-sociological problem were partly the same, partly quite different.

Another basic term, or rather pair of correlative terms, is "part" and "whole," a pair which very elusively seems to require redefinition as soon as we pass from one science to another. Thus to say that an angle is part of a triangle is quite different from saying that the earth is part of the solar system, and this in turn is quite different from saying that the hand is part of the body. It may even be ambiguous to say that a toenail, a hand, and the lungs are all parts of an organic whole. At any rate, this pair of terms is one that must be carefully examined in a wide variety of scientific contexts, as should "finitude and infinity." The word "life" is seemingly of interest only in biology, but at least its meanings to a virologist, a parasitologist, a vertebrate embryologist, and a psycologist are sufficiently varied to be well worth the trouble of explaining. And so on for quite a sizable list, including "time," "space," "motion," "cause," "evolution," "machine," and the like.

But there was a second list, of importance equal to the first, which consisted of terms used *about* the sciences rather than *in* them: terms such as "inquiry," "probability," "common sense," "induction," "theory and practice," and others of this type. Such methodological terms, however, can no more safely be introduced to the student in absence of concrete illustrative readings and demonstrations than can those of the first class; and consequently there was no thought of beginning the course with them. Most often, some such terms as these served to conclude the work.

But of course it was impossible to pack all these terms, which ran to nearly forty, into a term (be it a quarter or even a semester) and still make them meaningful; so, each time the course was offered a drastic reduction had to be made, and each class embarked on the study of no more than four or five of them. Great care had to be taken to select a set that would not unduly penalize those who had had considerable biology but little or no physics, or who had had college logic and mathematics but no laboratory science, and so on. Accordingly, I generally chose notions for which the best illustrative readings were in one group of sciences, then in another, and then still another. This made it advisable to discover what prior training the students had had; a show of hands was usually sufficient to indicate intended and declared majors, high school experience, and whatever else seemed relevant. Such a procedure had the effect, moreover, of keeping the work new and to some extent proportioned to the needs and aptitudes of each class. At the same time, the backlog of materials falling under each concept allowed a certain stability of organization. It is also interesting to note that some of the same little informal demonstrations could be used to point to more than one concept—for example those patches of felt which admirably exemplified the psycho-physical aspects of color could also be used to start a discussion on the pros and cons of a skeptical approach to the proposition that the reports of our senses are sure grounds for scientific knowledge. Perhaps this was being overly economical; but I should remind the reader that there is nothing so small as the budget for laboratory equipment and supplies in a department of philosophy.

III. My own view was that despite a good many limitations the course was a fair success, although it was eventually discontinued because of a university-wide change of the curriculum for all freshmen. It is hard to assess what benefits there were for the individual students, of whom there were about a thousand in all. The most exact estimation of the success of a course of this kind lies in exhibiting the basic principles by which instruction was carried on, and then asking how the methods of the course would comport with the aims. If we are to examine the sciences, or even a single science, we soon notice that our subject matter divides into statements of problems and statements of solutions. The history of science is such that the problems of one man are ordinarily not solved by the solutions of another—the first man would not concede that his quest had ended. We must view a scientist's problems and solutions in an orderly context, one that he builds up through the principles he selects, his illustrations, applications, deductions, conclusions, and further questions. This requires a careful appreciative reading of each man's text, and the awareness that the terms, propositions, and arguments must all fit together by a logic often dishearteningly peculiar to the writing under scrutiny. But through this close study of what a man says we can see the way he gives meanings to his terms, the kinds of truth, provisional or eternal, that he claims for his propositions, and the rigor he expects his proofs to exhibit. This effort to interpret the inner logic of an article or treatise is a more fruitful way to investigate scientific method than to rest on the dogmatic (and quite erroneous) assertion that every scientific work consists of four mechanically-arranged stages, or upon the remark that hypothesis is always prior to law. The student can come by this more flexible strategy to look at each piece of research or formulation with a new eye, and to discover what is truthful though perhaps embedded in what is partially wrong, vague, or nonsensical.

Differences in scientific conviction are not, as a rule, head-on oppositions. Only if a term is used unambiguously between two men can it be brought to flat contradictions. The successions of scientific ideas are based chiefly upon changes in terminology and hence misunderstandings, and although some scientific ideas are much better than others, it is not possible to classify them under the same logical headings, if only because their originators did not all learn logic out of the same book. A *tolerance,* then, based upon this sensitivity to the kinds of expressions of thought, should not be the least useful skill accruing from this particular philosophical approach.

The student, moreover, must learn for himself that although the scientist speaks in highly specialized language, he is also employing quite general concepts, such as those we listed earlier. When two taxonomists argue about rosebushes, they are concerned not only with the classification of these individual plants, but also with the very meaning of the concept "species." When Einstein asked whether space was limited, he was also asking for a meaning of the concept "limitation." It takes a nice eye for the student to see this, but if he be guided with sufficient care he can usually make fair strides in the direction, not of ordinary induction, but of a philosophic intuition which discerns the relation between a broad and a narrow concept. This may not be the interpretation ordinarily given of the nature of scientific thought, but this second skill in thinking, *intuitive exactness*, seems as much needed as tolerance, if we wish to study the development of scientific theory.

These are large aims indeed for an elementary course in the philosophy of science. On the other hand, why should we settle for substantially less among the intellectual virtues than the tolerance born of clearheaded insight?

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EFFECT OF DORMANT SEASON TEMPERATURE VARIABILITY ON PEACH FLOWER BUD HARDINESS

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ABSTRACT. — Temperature variability during the dormant period of peach trees was investigated by analysis of daily temperature data for 46 years at five locations representing the continental climate of Illinois. The standard deviation was used as the criterion of temperature variability, and the daily minimum and daily maximum temperatures were the most meaningful temperature measures investigated. The magnitude of temperature fluctuations about the mean was progressively greater at more northern locations in Illinois. Southern Illinois differs from the remainder of Illinois in having relatively similar temperature characteristics affecting peach flower bud hardiness during the dormant period. Fluctuations of the daily maximum temperature during the dormant period more frequently exceed the basal temperature (45° F.) for growth of peach trees at southern locations in Illinois than at northern locations. Temperature fluctuations exceeding the basal temperature are presumed to be responsible for observations of reduced dormant flower bud hardiness of specific peach varieties when grown in warmer climatic regions.

Many factors (Anonymous, 1959) influence the hardiness of peach flower buds to damage from low temperatures during the dormant season. In addition to the age, vigor and state of development of the plant, the following climatic factors are closely associated with the degree of hardiness expressed by the plant in a specific instance: the lowest temperature attained; the rate of cooling; the duration of the low temperature period; the date when low temperatures occur and the relative stability of the temperature, which includes the magnitude, frequency and duration of short-term temperature fluctuations.

Chaplain (1948) reported the killing point of peach flower buds fluctuated directly with temperature changes during the winter months. The greatest hardiness reached by flower buds coincided approximately with the date when the rest period was broken in mid-winter. Bradford (1922) used 43°F. as the basal temperature effective for the growth of many parts of temperate deciduous tree fruit plants. However, 45°F. has been extensively used as the basal temperature in more recent phenological studies with the chilling requirement of peach buds (Lammerts, 1949).

Blake (1933) and Mowry (1962) noted that flower buds of the Sunapee, Veteran, and Triogem peach varieties were classed as hardy during severe winters and in northern localities where low temperatures were extreme. The same varieties were regarded as less hardy to cold in mild winters and in southern localities characterized by the common occurrence of temperatures above 45°F. during the dormant season. Certain other varieties were classed as hardy during mild winters and classed as tender only during severe winters. Prairie Dawn, Halehaven, and Elberta varieties were rather uniformly resistant or tender to cold in both situations.

Two possible explanations for the fact that flower buds of different peach varieties seemingly differ in their ability to withstand winter temperature fluctuations are: (1) an explanation which directly associates the temperature variability data with the biological response of the fruit trees, and (2)that solely the magnitude of temperature fluctuations, *per se*, may be responsible for the contradictory observations on dormant peach flower bud hardiness. Because no specific information on the variability of temperatures or the magnitude of temperature fluctuations was found in the literature, it became necessary to test methods and determine the variability of winter temperatures at representative locations in the continental climatic regions of Illinois.

Although Illinois presents a wide range in climatic conditions because of the length of about 385 miles, Page (1949) found that seven stations with long-term weather records were apparently representative of the temperatures in Illinois: Dubuque, Iowa; Chicago; Peoria; Springfield; Urbana; St. Louis, Missouri; and Cairo. Joos (1960) noted that spring seemed to arrive about a month later at Freeport in northern Illinois than at Anna in southern Illinois. Baker (1936) also showed that the date when the average daily temperature rises above 45°F. occurs about four weeks later in the spring at Dubuque (April 16) than at Cairo (March 16).

Powell et al. (1960) divided Illinois into four fruit growing regions based upon the average date that a specific phenological event (such as the date of full bloom on apple varieties) occurred during the growing season. Each area was about one week later in development than the preceding area from south to north. These fruit growing areas are represented by specific weather stations: Cairo for Area A, St. Louis for Area B, Springfield for Area C, and Peoria and Moline for Area D. Dubuque is included in the preliminary analyses for information at the extreme northern limit of Illinois.

Methods of Determining Temperature Variability

For the preliminary analyses the dormant season was defined as the months with an average monthly temperature less than 45°F. The average monthly temperature is the average of the average daily temperatures during the month. The average daily temperature is the average of the maximum and the minimum temperatures recorded for the day. The dormant season of Cairo and St. Louis included the winter months of December, January and February. The dormant season for Springfield, Peoria and Dubuque included November and March in addition to the winter months. Baker (1936) presented maps showing long-term average dates when the average daily temperature fell below and rose above 45°F. and the duration of the dormant periods at the locations was obtained from these maps (Table 1). For the IBM computer analyses the dormant season for peach trees was defined as the period when the average daily temperature was continuously less than 45°F.

In the absence of literature describing suitable techniques for determining temperature variability, a

TABLE 1.—Length of Dormant Period and Variability of Lowest Temperatures Recorded at Selected Locations Representing Illinois for the Dormant Periods[1] of 65 Years, 1881 Through 1945.

Location	Dormant period[2]			Lowest temp. °F.	Mean annual lowest temp. °F.	Signif.[3]	Std. dev.	Coef. var. %
	Start	End	Days					
Cairo	Nov. 21	Mar. 15	115	—16	3	d	4.4	.95
St. Louis	Nov. 13	Mar. 24	132	—22	—3	d	5.8	1.28
Springfield	Nov. 9	Apr. 1	144	—24	—8	c	6.9	1.53
Peoria	Nov. 5	Apr. 6	153	—27	—12	b	7.4	1.66
Moline	Nov. 1	Apr. 9	160					
Dubuque	Oct. 30	Apr. 13	166	—32	—17	a	6.6	1.49

[1] Dormant periods in the preliminary analyses are the months of November through March for Dubuque, Peoria and Springfield; and December through February for St. Louis and Cairo.
[2] From Baker (1936) and used for IBM computation.
[3] Locations followed by the same letter are not significantly different at the 5 per cent level of probability.

preliminary measure of temperature variability used was data on annual lowest temperatures recorded during the dormant periods of 65 years, 1881 through 1945, at five locations as reported by Page (1949). The lowest temperature is defined as the single lowest temperature recorded in the period. Average temperatures are considered unsuited to studies of temperature variability because extreme temperatures are deliberately sacrificed in the calculation of averages.

In preliminary analyses the variance, standard deviation and coefficient of variation was calculated for each of the following locations independently: Cairo, St. Louis, Springfield, Peoria and Dubuque. The standard deviation characterized the variability of temperatures about the mean at each location. The relative variability between locations was determined from the coefficient of variation.

In order to determine temperature variability more precisely, four temperature measures were investigated by IBM computer calculations: the daily minimum temperature (A), the daily maximum temperature (B), the product of the daily maximum and daily minimum temperatures (AB) and the difference between the daily maximum and daily minimum temperatures (B-A). Data on these temperature measures were available on IBM cards for Cairo, St. Louis, Springfield, Peoria and Moline.

Two types of analysis were calculated with the IBM Model 1401 computer. First, an analysis of variance was calculated with each temperature measure for five locations and 46 years, 1909 through 1955. The standard deviation of each location indicated the variabiiity of temperatures around the mean for each temperature measure.

For the second analysis the raw data for the four temperature measures over 46 years at each location individually was summarized in 10-day segments spanning the total dor-

TABLE 2.—Mean Temperatures and Temperature Variabilities of three Temperature Measures for the 115-day Dormant Period and the Full Dormant Period at Five Locations Representing Illinois Over 46 Years, 1909 Through 1955.

Temperature measure and location	115-day dormant pd.			Full dormant pd.			Difference between means	Diff./ S. E. Diff.	Difference between Std. dev.
	Mean °F.	Signif.[1]	Std. Dev.	Days	Mean °F.	Std. Dev.			
Daily minimum temp. (A)	(F=1005.62**)[2]								
Cairo	32.22 ± .15	a	10.57 ± .08	110	31.89 ± .15	10.54	.33	1.57	.03
St. Louis	28.43 ± .15	b	11.09 ± .08	130	29.51 ± .14	10.83	1.08	4.91**	.26
Springfield	24.51 ± .16	c	11.34 ± .08	130	25.64 ± .14	11.02	1.13	5.14**	.32
Peoria	21.18 ± .16	d	11.97 ± .08	150	24.00 ± .14	11.27	2.82	12.26**	.70
Moline	19.73 ± .17	e	12.41 ± .08	160	23.68 ± .13	11.35	3.95	16.46**	1.06
Daily maximum temp. (B)	(F=832.72**)								
Cairo	47.99 ± .17	a	12.17 ± .09	110	47.38 ± .17	11.94	.61	2.54*	.23
St. Louis	44.29 ± .18	b	12.96 ± .09	130	45.55 ± .16	12.69	.26	1.04	.27
Springfield	39.78 ± .17	c	12.45 ± .09	130	41.15 ± .16	12.13	1.37	5.48**	.32
Peoria	37.34 ± .17	d	12.26 ± .09	150	40.83 ± .14	11.98	3.49	14.54**	.28
Moline	35.46 ± .17	e	12.45 ± .09	160	40.06 ± .14	12.16	4.60	18.40**	.29
Product (AB)	(F=1094.98**)								
Cairo	113.69 ± .14	e	10.38 ± .07	110	104.53 ± .14	10.23	9.16	43.60**	.15
St. Louis	126.18 ± .15	c	10.94 ± .08	130	112.85 ± .14	10.63	13.33	60.59**	.31
Springfield	124.79 ± .15	d	10.86 ± .08	130	109.39 ± .14	10.47	15.40	73.33**	.39
Peoria	128.05 ± .15	b	10.98 ± .08	150	107.08 ± .12	10.36	20.97	95.32**	.62
Moline	136.85 ± .16	a	11.33 ± .08	160	109.67 ± .12	10.52	27.18	123.55**	.81

[1] Means followed by the same letter are not significantly different at the 1 per cent level of probability.
[2] Single and double asterisks indicate values significant at .05 and .01 levels of probability, respectively.

mant period. The calendar dates delimiting the 10-day segments were identical for all five locations. An analysis of variance for each location individually was calculated to determine differences between the means and the standard deviations of the 10-day segments.

Finally, the mean temperatures and standard deviations at each location obtained by the two types of analysis were compared by using the t test and standard error of the difference between means.

Results of Temperature Variability Analyses

A minimum of the temperature variability results are included here to assess the biological effects on dormant peach flower bud hardiness. A more complete presentation of the methods and results of determining temperature variability will be published in another paper. In the preliminary analyses the mean annual lowest temperature (Table 1) was significantly different for all locations excepting Cairo and St. Louis, and the respective standard deviations indicated that the annual lowest temperatures were more variable at northern locations than at southern locations. The similarity of the Cairo and St. Louis means indicated that southern Illinois differs from the remainder of Illinois in having relatively similar temperature characteristics during the dormant period. In unpublished preliminary analysis of other temperature measurements comparisons of the temperature variability of the locations using the standard deviation versus the coefficient of variation led to opposite conclusions. Thus, the preliminary results were inconclusive with regard to interpreting the biological significance of the data.

Presumably, the greatest precision would be obtained by using daily data rather than monthly or annual data. The first type of analysis with the IBM Model 1401 computer was an analysis of variance using data for a standardized 115 day dormant period from all locations combined as the basis for determining the error variance (Table 2). Highly significant F values and differences between means of all locations were found for three temperature measures: the daily minimum temperature (A), the daily maximum temperature (B), and the product of the daily minimum and maximum temperatures (AB). The latter temperature measure did not contribute additional information to that provided by the first two temperature measures, and the biological significance was less evident. Therefore, the product will not be considered further as a measure of temperature variability. The fourth temperature measure, the difference between the daily maximum and daily minimum temperatures (B-A), showed no significant differences in any of the analyses and was of little use in analyzing differences in temperature variability. The mean daily minimum and daily maximum temperatures were progressively higher at more southern locations. The variability of the daily minimum temperature, according to the respective standard deviations, was progressively greater at more northern locations and was correlated with the latitude of the locations and negatively cor-

TABLE 3.—Comparison of Percentile Group Ranks[1] for Temperature Variability During 10-day Segments of the Dormant Periods Over 46 Years, 1909 Through 1957, at Five Locations Representing Illinois.

Segments		Daily maximum temp. (A)						Daily maximum temp. (B)						Product (AB)					
No.	Dates	Cairo	St. Louis	Springfield	Peoria	Moline	Avg. Rank	Cairo	St. Louis	Springfield	Peoria	Moline	Avg. Rank	Cairo	St. Louis	Springfield	Peoria	Moline	Avg. Rank
1	Nov. 1 —Nov. 10				9	9	9.0				6	7	6.5				10	10	10.0
2	Nov. 11—Nov. 20		6	7	7	8	7.0		5	3	2	2	3.0		5	6	6	7	6.0
3	Nov. 21—Nov. 30	10	10	10	9	9	9.6	9	10	7	8	8	8.4	10	10	10	7	10	9.4
4	Dec. 1 —Dec. 10	1	1	2	3	4	2.2	5	7	5	6	8	6.2	2	3	2	2	5	2.8
5	Dec. 11—Dec. 20	2	4	4	5	4	3.8	6	8	7	8	8	7.4	3	5	5	10	5	5.6
6	Dec. 21—Dec. 30	7	5	4	3	4	4.6	10	10	10	10	10	10.0	9	8	8	8	7	8.0
7	Dec. 31—Jan. 9	3	2	1	1	1	1.6	4	6	6	6	5	5.4	3	4	4	2	1	2.8
8	Jan. 10—Jan. 19	3	2	2	3	3	2.6	4	7	7	7	6	6.2	3	6	6	6	6	5.4
9	Jan. 20—Jan. 29	3	1	3	1	4	2.4	4	6	7	6	6	5.8	4	5	7	6	6	5.6
10	Jan. 30—Feb. 8	2	2	1	2	3	2.0	3	6	6	7	6	5.6	2	4	4	4	4	3.6
11	Feb. 9 —Feb. 18	3	1	1	3	2	2.0	1	1	1	1	1	1.0	1	1	1	1	1	1.0
12	Feb. 19—Feb. 28	8	7	7	6	5	6.6	4	5	5	7	7	5.6	7	7	8	8	7	7.4
13	Mar. 1 —Mar. 10	8	6	8	7	7	7.2	5	5	3	5	6	4.8	6	5	6	7	8	6.4
14	Mar. 11—Mar. 20		7	9	9	8	8.3		5	4	5	5	4.8		7	9	10	10	9.0
15	Mar. 21—Mar. 30				10	10	10.0				1	1	1.0				8	10	9.0
16	Mar. 31—Apr. 9					10	10.0					4	4.0					10	10.0

[1] Percentile group rank for the variance: rank 1 is most variable, rank 10 is least variable.

related with the location means. With the daily maximum temperature, the trend of the standard deviations of the locations was inconclusive and showed little correlation with the respective latitudes or location means.

In the second type of analysis each location was investigated independently by analysis of variance of the entire dormant period divided into 10-day segments (Table 2). At each location the segments factor also had a highly significant F value with the A, B and AB temperature measures, and the F values for the B-A temperature measure again were uniformly not significant. The conclusions regarding the mean temperatures and the magnitude of temperature variability at the locations were identical with those obtained in the first type of analysis.

The percentile ranks for temperature variability are assembled in Table 3 and grouped by dormant period segment and by location to facilitate comparisons. The general temperature pattern during the dormant period was not the same for the two temperature measures. For the daily minimum temperature, the lowest mean temperature occurred in segment 9, January 20 through 29, and the highest mean temperature occurred in the extreme end segments of the dormant period at all locations. The magnitude of variability was generally greatest in segments 7 through 11, the middle of the dormant period, and the extreme ends of the dormant period showed the least variability. At Cairo and St. Louis the most variable temperatures occurred in segment 4, December 1 through 10, or one month earlier than segment 7, the most variable segment at Springfield, Peoria and Moline. This observation lends support for the observation that southern Illinois differs from the remainder of Illinois in having relatively similar temperature characteristics during the dormant period.

For the daily maximum temperature, the lowest mean temperature occurred in segment 7, December 31 through January 9, and the highest mean temperature occurred in the extreme end segments of the dormant period at all locations. The greatest temperature variability was restricted to segment 11, from February 9 through 18, and the least variability was restricted to segment 6, from December 21 through 30, at all locations.

The location means for the significant temperature measures, as determined from the two types of IBM computer analysis, are compared in Table 2. With the daily minimum temperature the means were significantly different at all locations except Cairo, where the dormant period used in both types of analyses was very similar, and the means of the daily maximum temperature were significantly different at all locations except St. Louis. Little difference was noted between the standard deviations obtained by the two types of analysis. This observation emphasizes the fact that the greatest variability of temperatures occurs within the 110-day portion of the dormant period, November 21 through March 15 at all locations.

Discussion

In considering the two explanations for the fact that flower buds of different peach varieties seemingly differ in their ability to withstand winter temperature fluctuations, the first explanation, wherein temperature fluctuations may exceed the basal temperature (45°F.) required for growth of deciduous tree fruit plants, directly associates the climatic data with the biological response of the fruit trees. An examination of Table 2 reveals that the mean daily maximum temperature at Cairo is 48°F., and the standard deviation indicates that two thirds of the daily maximum temperatures during the dormant periods will be within the range of 36° to 60°F. The mean daily maximum temperatures are progressively lower at more northern locations. Thus, at Moline the mean daily maximum temperature is about 35°F., and two thirds of the daily maximum temperatures will be within the range of 25° to 48°F. In comparing these extreme locations in Illinois it is apparent that daily maximum temperatures will exceed the basal temperature for peach tree growth (45°F.) during the dormant period much more frequently at Cairo than at Moline. The same tendency is revealed in a study of the daily minimum temperatures. Chaplin (1948) reported the killing point of peach flower buds fluctuated directly with temperature changes during the winter months. Therefore, the greater frequency of temperature fluctuations exceeding 45°F. in southern locations than in northern locations is likely to be responsible for the contradictory observations of reduced flower bud hardiness on peach trees of the same variety grown in a warmer continental climatic region. A more precise estimate of the temperature fluctuation frequencies must await a different type of temperature analysis—perhaps an enumeration of the days when temperatures exceed the basal temperature, or possibly a degree-days summation at each location.

The second explanation, concerned solely with the magnitude of temperature fluctuations, has not been substantiated. The variability of temperatures about the mean is smaller at southern locations than at northern locations within the continental climate of Illinois. This conclusion holds true with a variety of temperature measures: the daily minimum temperature, daily maximum temperature, the product of the first two measures, and the annual lowest temperature. Therefore, temperature variability, *per se*, cannot be responsible for the observation that peach varieties with hardy flower buds in northern locations may be considerably less hardy when the variety is grown in southern locations with considerably warmer dormant period temperatures.

Chaplin (1948) noted that the greatest hardiness of peach varieties at Olney, Illinois, occurred between December 15 and January 10 during a three year period. This period of greatest hardiness of peach varieties should occur in January because the lowest mean daily minimum and maximum temperatures occur in the month of January throughout the state. During the dormant periods of the past six years, 1957 through 1963, at Carbondale, a total of 1200 hours of temperatures below 45°F. have accumulated by January 1 through 10 (Mowry, unpublished data). At Olney the 1200 hour total should accumulate by December 24 through January 1. Since 1200 hours of temperatures below 45°F. will break the rest period of flower buds of practically all peach varieties, Chaplin's statement that the period of greatest bud hardiness of peach varieties coincided with the breaking of the rest period is generally confirmed.

Summary

Temperature variability during the dormant period of peach trees was investigated by analysis of daily temperature data for 46 years at five locations representing the continental climate of Illinois. The standard deviation was used as the criterion of temperature variability, and the daily minimum and daily maximum temperatures were the most meaningful temperature measures investigated.

The magnitude of temperature fluctuations about the mean was progressively greater at more northern locations in Illinois. The two major parameters exhibited a different pattern of variability during the dormant period at each location. The variability of the daily minimum temperature was generally greater in the middle of the dormant period, and the extreme ends of the dormant period showed the least variability. At Cairo and St. Louis the most variable segment occurred about one month earlier than at Springfield, Peoria and Moline. For the daily maximum temperature the most variable segment of the dormant period was February 9 through 18, and the least variable segment was December 21 through 30 at all locations.

When considering the average of both parameters, the February 9 through 18 segment had the greatest variability, and the November 21 through 30 segment had the least variability at all locations.

Southern Illinois differs from the remainder of Illinois in having relatively similar temperature characteristics affecting peach flower bud hardiness during the dormant period.

Fluctuations of the daily maximum temperature during the dormant period more frequently exceed the basal temperature (45°F.) for growth of peach trees at southern locations in Illinois than at northern locations. Temperature fluctuations exceeding the basal temperature are presumed to be responsible for observations of reduced dormant flower bud hardiness of specific peach varieties when grown in warmer climatic regions.

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VEGETATION DEVELOPMENT ON A STRIP-MINED AREA IN SOUTHERN ILLINOIS

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ABSTRACT.—The floristic composition and vegetative characteristics of a strip mine planted to black locust and to shortleaf pine in Perry County of southern Illinois were examined. The understory cover was denser under black locust, which had more typically mesic forest species. The sparser ground cover under pine included numerous old-field species. Both areas gave early evidence of succession to a forest rich in oaks.

The thousands of acres of strip-mine lands in the central United States carry a great diversity of vegetation (Brewer and Triner, 1956; Verts, 1957; Limstrom, 1960). This results from a variation in management and planting practices on the "new" land by mine operators, from differential survival and growth of planted species, and from the extent of natural plant invasion. Black locust has been recommended to comprise 25 to 50 percent of a species mixture for strip-mine plantings on poor sites because of its beneficial effects on associated species and on the soil (Boyce and Merz, 1959; Boyce and Neebe, 1959; Limstrom, 1960). Its fast growth is often offset by repeated attacks of the locust borer. Shortleaf pine is desirable for wood products and erosion control. The present study reports the species naturally occurring under plantings of these two overstory species and thus serves as a record of a stage in the natural succession on the study areas. Differences in the present understory vegetation appear to have been brought about by the environmental modifications under the two plantations, emphasizing the importance of autogenic factors in succession.

Vegetation has been related to environment by the formulation: Vegetation is a function of the regional climate, parent material, relief or topography, and organisms potentially able to invade, all operating in the context of time. The study areas have been available for plant occupancy for 25 years, and no consistent differences in regional climate, parent material, or relief were observed between them. The floral and faunal factors can be considered essentially uniform. Both areas, surrounded by strip-mined lands, or roads, appear to be equally within the effective range of plant propagule dissemination or animal migration for the species found in the general vicinity. Possible differences between the black locust and the pine, such as perching preferences for birds carrying seed from fruit eaten earlier, would accentuate the role of cover type on subsequent development of vegetation. Those differences observed and reported here appear rather to be a resultant of the effects of the original plantation trees on the environments, particularly on the soil nutrient levels (Baker and Ashby, 1963). The total effect appears to be cumulative, with the black locust areas more shaded at the ground surface as a result of vigorous growth of the ground layer, and with more evident animal activity.

Materials and Methods

The present study areas were stripped in 1935 as part of the Fidelity Mine of the United Electric Coal Co. in Perry County about four miles west of DuQuoin, Illinois. In 1938 and 1939 black locust (*Robinia pseudoacacia*) and shortleaf pine (*Pinus echinata*) were planted in separate adjacent areas. Eight years later two adjacent one-half acre experimental plots in each overstory area were further underplanted with nine tree species (Mather et al., 1947). The black locust (many riddled by locust borer) then averaged about 22 feet in height with 1,200 survivors from the original 2700 trees per acre. The shortleaf pine averaged less than six feet in height with about 700 remaining from the original 1200 per acre.

By 1962-63 further mortality and growth of the remaining trees had taken place. Approximately 400 black locust and 650 pine trees per acre remained. Although the locust had sprouted, it continued to show damage from locust borer and the pine from tip moth and other causes. Many of the pines appeared to have low vigor. There were some resultant open places. On the other hand, localized areas in both the black locust and the pine had enhanced coverage from the growth of those underplanted trees which survived and from natural tree invasion. The canopy was closed over much of both areas. The crowns of both the black locust and the shortleaf pine were, however, relatively light. Total basal area based on diameter measurements at breast height (DBH) for all size classes of all species ranged from 65 to 70 square feet per acre for the one locust and the two pine plots, to 95 square feet per acre for the second locust plot. The plantation pine constituted over 90% of the basal area, and the locust 70% or more in those plantations.

Collections of all naturally invading plant species were made in both overstory areas from the summer of 1962 to that of 1963. The usual procedure was to walk along a ridge through one given overstory, return along the flat-bottomed troughs, repeat the first direction along a second ridge, and so forth. The slopes were checked for new species from both the troughs and the ridges. The ridges trended north-south, ranging from 2 to 20 feet in height with an average about 10 feet, and the crests ranged from 50 to 150 feet apart, usually with a trough 5 to 50 feet wide. For the most part the slopes were steep, somewhat slumped from the angle of repose, and could be walked up with some difficulty. The parent material was a silty clay with rocky phases and a pH value of approximately 7 in most areas sampled. Drainage appeared to be internal. Temporary impoundments in local low-lying areas supported willows and associated herbaceous species. These areas, and other fully open areas, were not used for collection sites.

As a rule a specimen for each species reported was taken, pressed, and deposited in the Southern Illinois University Herbarium. Exceptions were a few common species collected

TABLE 1.—Species Present in the Strip Mine Areas West of DuQuoin, Illinois.

A. Species found only in the black locust plantation.

Herbaceous—*Allium canadense* Wild Garlic, *Ampelamus albidus* Climbing Blue-vine, *Arctium minus* Common Burdock, *Arisaema dracontium* Green Dragon, *Asplenium platyneuron* Ebony Spleenwort, *Bromus commutatus* Bromegrass, *Chenopodium album* Lamb's Quarters, *Erechtites hieracifolium* Fireweed, *Geranium carolinianum* Carolina Cranesbill, *Muhlenbergia sp.* Muhly Grass, *Oxalis dillenii* Yellow Woodsorrel, *Poa compressa* Canada Bluegrass, *Polygonatum canaliculatum* Solomon's Seal, *Polygonum convolvulus* Black Bindweed, *Ranunculus abortivus* Small-flowered Buttercup, *Rumex crispus* Curly Dock, *Solidago sp.* Goldenrod, *Sphenopholis obtusata* Prairie Wedgegrass, *Spiranthes sp.* Ladies'-tresses Orchid, *Taraxacum officinale* Common Dandelion, *Teucrium canadense* Wood Sage, *Viola missouriensis* Missouri Violet, *Viola rafinesquii* Johnny-jump-up.
Trees—*Celtis occidentalis* Hackberry, *Quercus alba* White Oak.

Fifteen additional species noted as present 8 years after the plantations were established (Mather, et al., 1947) and not found in 1963 were: Aster, *Erigeron sp.*, *Lactuca*, Mullein, *Myosotis virginiana*, *Oxalis stricta*, *Parietaria pennsylvanica*, Plantain, Ragweed, *Rumex acetosella*, *Solanum carolinense*, *S. dulcamara*, Sweet Clover, Raspberry, and White Ash.

B. Species found in both the black locust and the shortleaf pine plantations.

Herbaceous—*Acalypha gracilens* Slender Three-seeded Mercury, *Apocynum sibiricum* Dogbane, *Botrychium virginianum* Rattlesnake Fern, *Eupatorium rugosum* White Snakeroot, *Galium aparine* Cleavers[1], *Geum canadense* White Avens, *Geum vernum* Spring Avens, *Phytolacca americana* Pokeweed[1,2], *Sanicula canadensis* Short-styled Snakeroot, *Triodanis perfoliata* Venus' Looking-glass.
Shrubs and Vines—*Campsis radicans* Trumpet Vine, *Parthenocissus quinquefolia* Virginia Creeper[1], *Rhus radicans*, Poison Ivy, *Rubus flagellaris* Dewberry[1,2], *Vitis aestivalis* Summer Grape[2].

Trees—*Acer negundo* Box-elder, *Morus rubra* Red Mulberry[1], *Platanus occidentalis* Sycamore[2], *Populus deltoides* Cottonwood[1,2], *Prunus serotina* Wild Black Cherry[1], *Quercus imbricaria* Shingle Oak, *Quercus rubra* Red Oak, *Robinia pseudoacacia* Black Locust, *Ulmus alata* Winged Elm, *Ulmus americana* American Elm[1,2], *Ulmus rubra* Slippery Elm.

C. Species found only in the shortleaf pine plantation.

Herbaceous—*Allium vineale* Field Garlic, *Ambrosia artemisiifolia* Small Ragweed, *Andropogon virginicus* Broomsedge Grass[2], *Antennaria sp.* Everlasting[2], *Aster pilosus* Aster[2], *Brachyeletrum erectrum* Short Husk Grass, *Cassia fasciculata* Partridge Pea, *Cassia nictitans* Wild Sensitive Plant, *Cirsium sp.* Thistle, *Convolvulus sp.* Bindweed[2], *Crotalaria sagittalis* Rattlebox, *Daucus carota* Wild Carrot, *Desmodium sp.* Tick Trefoil, *Erigeron annuus* Common Fleabane, *Euphorbia corollata* Flowering Spurge, *Gnaphalium obtusifolium* Sweet Everlasting, *Melilotus officinalis* Yellow Sweet Clover, *Panicum hauchuche* Panic Grass, *Pycnanthemum flexuosum* Mountain Mint, *Setaria lutescens* Yellow Foxtail Grass, *Solanum nigrum* Black Nightshade, *Solidago ulmifolia* Elm-leaved Goldenrod, *Solidago sp.* Goldenrod, *Sonchus oleraceus* Common Sow-thistle.

Shrubs and Vines—*Rhus copallina* Shinning Sumac, *Rhus glabra* Smooth Sumac.
Trees—*Diospyros virginiana* Persimmon, *Juniperus virginiana* Red Cedar, *Pyrus sp.* Crabapple, *Salix nigra* Black Willow[2].

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[1] Species noted as present in the black locust plantation eight years after planting (Mather, et al., 1947).

[2] Species noted as present in the shortleaf pine plantation eight years after planting. Five additional species listed then which were not found in 1963 were: *Asclepias verticillata*, *Lactuca sp.*, *Lepidium sp.*, Mullein, and *Oenothera sp.*

from one area and not duplicated from the other, or inadvertently omitted from both. They are reported as sight records. Nomenclature followed Mohlenbrock and Voigt (1959).

Results and Discussion

The ground cover was denser and taller in the areas originally planted to black locust. One walked through knee-high herbs over much of the area. In contrast, the ground cover was scanty over much of the pine stand, with a pine needle carpet generally evident. In mid July, 1963, an ecology class found 8 species on single plots of the bottom, ridge, east- and west-facing slopes under the black locust overstory. These averaged 60 plants which totaled 90 grams dry weight per square meter. The bottom had the densest vegetation. Equivalent average values for the pine area were 41 plants of 14 species weighing 28 grams. These values suggest the vegetational relationships of the two areas.

The floristic analysis is given in Table 1. Woody plant invaders were about half as numerous as the herbaceous. In terms of their usual ecological relationships, the species for the two areas differed. Those under the black locust, such as green dragon, Solomon's seal, and Missouri violet were typical of mesic forested areas. Herbs such as white snakeroot and avens formed large masses of ground vegetation. Under the pine were species more typical of old fields such as aster, small ragweed, broomsedge, wild carrot, sumac, and persimmon. Growth of these species under the pine was limited, generally with scattered individuals. An exception was sweet clover which formed occasional patches in open areas within the pine.

Twenty-five species were distinctive to the black locust and 30 to the pine, with 26 species common to both. A United States Forest Service planting record in 1947, 8 years after the original plantations were established, noted volunteer plants present at that time. Fifteen of those species were found in 1963. Ten were in both plantations and five in the pine only. None remained distinctive under the black locust. Twenty were not found at all in 1963. Of these, fifteen had been noted for the locust and five from the pine areas. These figures suggest a lesser modification of the environment by pine in the years from 1947 to 1963.

Strip mining usually proceeds rapidly and disturbs large areas at a time. Perry County had been cleared to a great extent for agriculture. Remaining upland wooded areas have an oak-hickory cover (Voigt and Mohlenbrock, in press). Forests of the mesic ravines include tulip tree (*Liriodendron tulipifera*) and ash (*Fraxinus sp.*), while cottonwood, elm, hackberry, sycamore and willow are often found along streams.

The naturally invading tree species which reached canopy size in the locust areas included approximately one each per acre of hackberry, sycamore (the largest tree 14.9 inches DBH), wild black cherry, and American elm, a very low number which would not serve to establish a stand. To be sure, part of the area had the underplanted hardwoods, many of which survived and would appear to constitute the next tree generation where planted (Boyce and Neebe, 1959, p. 9; Limstrom, 1960, p. 55; Casteel, 1963). The general picture, however, was that the black locust had been sufficiently closed to eliminate nearly all natural tree regeneration. The subsequent invasion by those tree species listed in Table 1 may ultimately be more successful.

In the pine area three invading tree species of canopy size were found — cottonwood, sycamore, and, adjacent to as well as in the temporarily inundated bottoms, willow. One of 8 cottonwoods on the two half-acre plots was 18.4 inches DBH. Half of the cottonwoods were in troughs and the others either on the slopes or the ridges. All three sycamores were on the ridges. The other 3 canopy species of the black locust areas were not found under the pine. The underplanted hardwoods showed better survival but less good growth than in the black locust. In general, the pine site appeared to have been more open for establishment of canopy trees than the locust site. Even so, the cottonwood and sycamore fall far short of forming a canopy, and other species including shrub-size oaks appear to be the advance guard of the naturally invading next tree generation.

The ultimate origin of most of the invading species can be explained by bird or wind distribution. More difficult to explain at present are species such as buttercup, violets, and oaks. Squirrels were not observed on the study areas. Hickories and walnuts were not found. A good explanation for the rather numerous young oaks in all areas is not presently available. Verts (1959) on another study area in Perry County found scanty evidences of squirrels on strip-mined lands. His areas included patches of remaining oak woods.

The second ingredient of invasion, a suitable habitat, differs for the two areas. Test species on the two soils in pot culture showed a highly significantly greater growth on the soil from the black locust than from the pine area (Baker and Ashby, 1963). This difference was eliminated by fertilizing with nitrogen at 200 pounds per acre on an elemental nitrogen basis. This would be equivalent to approximately 400 pounds per acre of a high analysis fertilizer such as urea. Nodules were found on the black locust roots. The greater nitrogen nutrient capital of the black locust soil would be a major factor favoring the growth of virtually all species. Actually, herbaceous legumes (*Cassia*, *Crotalaria*, *Desmodium*) were relatively much more important in the pine, though still sparse except for the localized patches of sweet clover in openings.

The essentially continuous mat of pine needles would be a deterrent to establishment of some species. Another factor difficult to evaluate is the more abundant animal life, evidenced by ground-hog holes and ant hills, in the black locust areas. Whether the animal life and the vigorous undergrowth are both responses to a common factor or whether one can be assigned as cause and the other effect was not determined.

Acknowledgments

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CORRELATION OF KAOLINITE MORPHOLOGY AND CRYSTALLINITY

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ABSTRACT. — Samples of kaolinite displaying various degrees of crystallinity determined by x-ray analysis were selected for electron microscope study to determine the relationship of kaolinite crystallinity and morphology. The hexagonal outlines of kaolinite platelets were found to be associated with both ordered and disordered kaolinite, suggesting that the hexagonal shape is conditioned by some factor other than perfection of internal order.

This report presents the results of a study of the morphology of kaolinite as related to crystallinity to determine if the hexagonal outline of kaolinite is always associated with well-developed crystallinity. Three samples of kaolinite, selected by X-ray analysis to show different degrees of crystallinity, were used for the electron microscope study: (1) a Cretaceous clay, commonly called Georgia kaolinite, from the Georgia Kaolin Company, Dry Branch, Georgia; (2) a Cretaceous—Tertiary clay from Anna, Illinois; and (3) a Pennsylvanian flinty clay from Vigo County, Indiana.

Unfractionated clay was gently ground to a fine powder and X-rayed in a diffraction unit (CuK α radiation, Ni filter, 1° slit). The dispersion technique was used to prepare the kaolinite for electron microscope study. Drops of dispersed clay were dried on copper 200-mesh electron microscope grids. Electron photomicrographs were taken of selected fields.

The degree of crystallinity is defined to include the degree of disorder within the crystallographic unit layer and the stacking variations of the unit layers (Murray, 1954). Murray used the following criteria to determine the degree of crystallinity by use of X-ray techniques: (1) sharpness of reflections; (2) number of reflections; (3) amount of shift in the (001) or basal spacing from the normal position; (4) resolution of closely spaced reflections; and (5) absence of certain reflections. The resolution of closely spaced reflections provides the best indication of the degree of crystallinity. Murray stated that the closely spaced reflections on a powder photograph of kaolinite with a good degree of crystallinity are well resolved as exemplified by reflections adjacent to the (020) and the (003) reflections, while these reflections are hazy and less resolved with poorer crystallinity. The coupling of the (020) $(1\bar{1}0)$ $(\bar{1}\bar{1}1)$ $(1\bar{1}\bar{1})$ reflections into a band indicates the disordered state described by Hendricks (1939) and discussed by Brindley and Robinson (1946). They stated that the disorder is the result of displacement of layers occurring in the b-direction only and of a magnitude of nb/3. This type of randomness of layers leaves reflections of types $K = 3n$ unaffected but diffuses all combinations for which $K \neq 3n$ (Brindley and Robinson, 1946).

Murray and Lyons (1956) studied kaolins displaying various degrees of

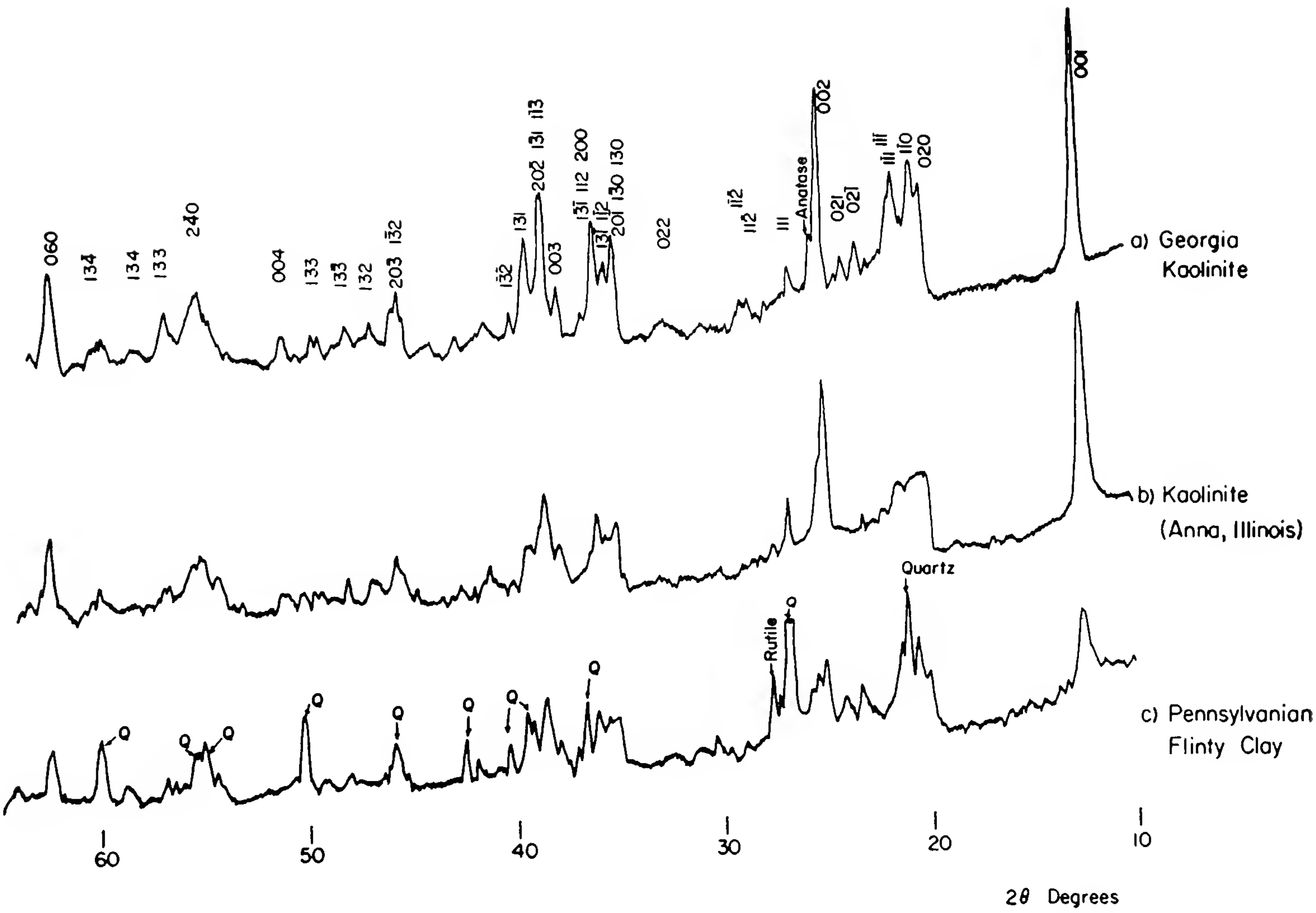

FIGURE 1.—X-ray diffraction patterns of three kaolinite samples from the Georgia Kaolin Co., Anna, Illinois, and Vigo County, Indiana.

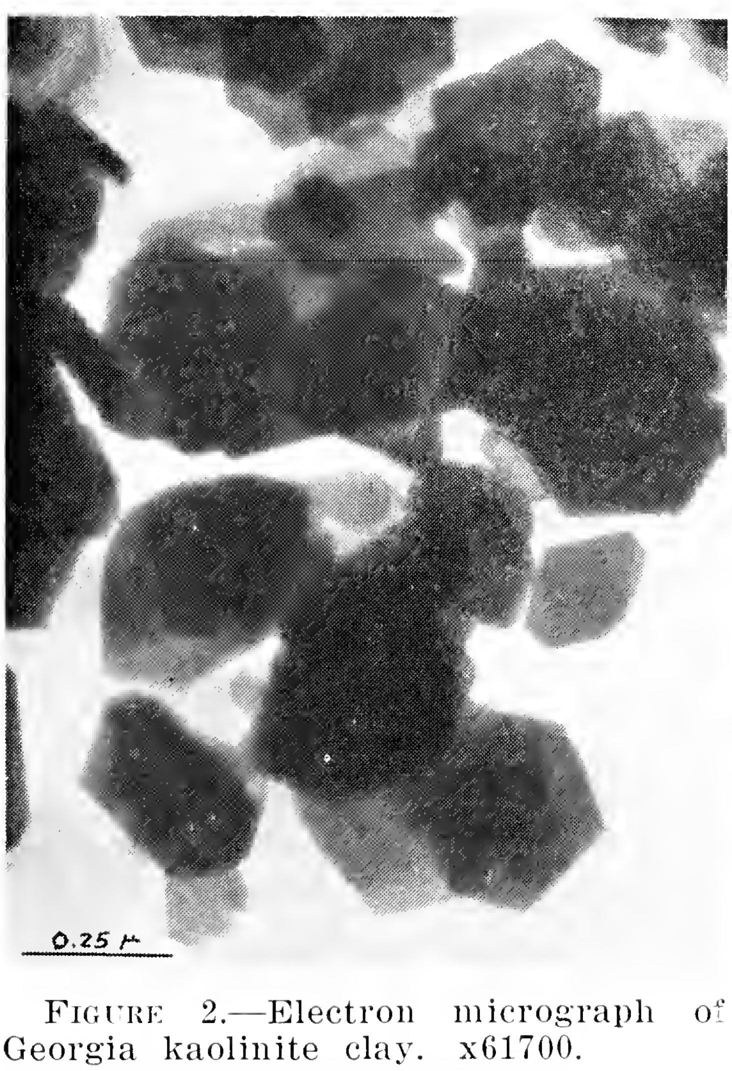

FIGURE 2.—Electron micrograph of Georgia kaolinite clay. x61700.

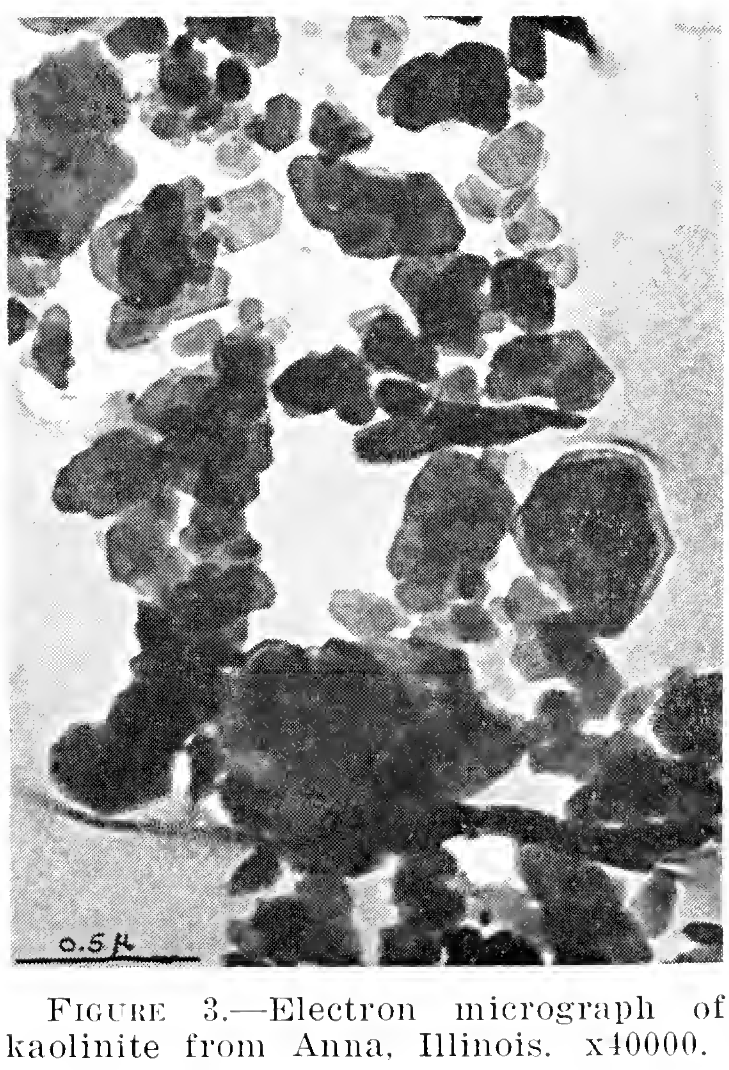

FIGURE 3.—Electron micrograph of kaolinite from Anna, Illinois. x40000.

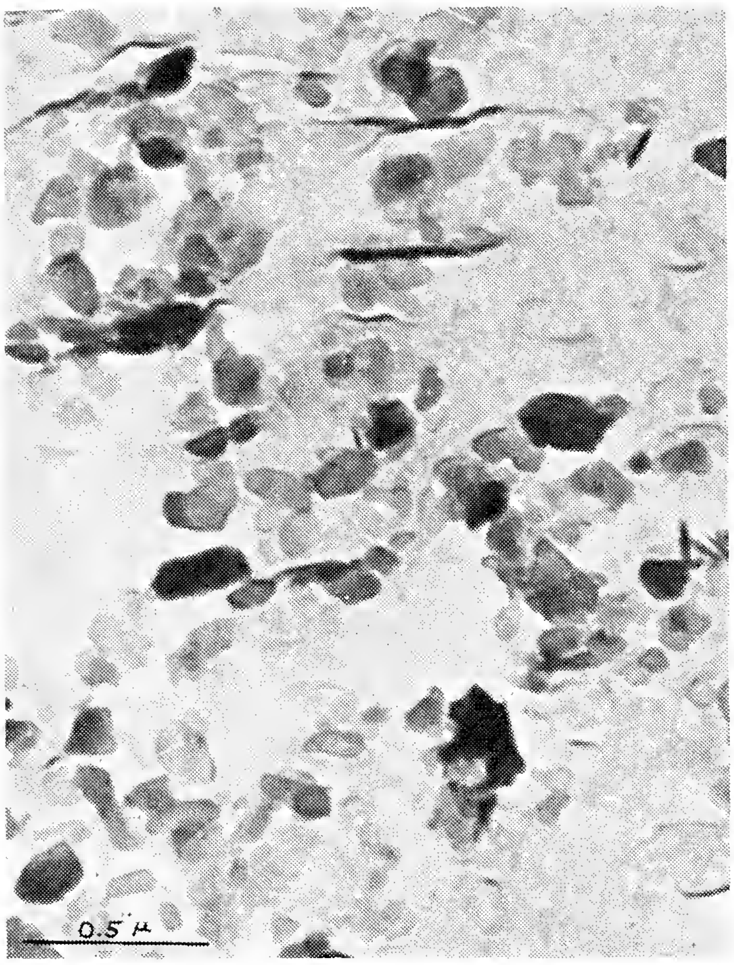

FIGURE 4.—Electron micrograph of a Pennsylvanian flinty clay, Vigo County, Indiana. x40000.

crystal perfection. From X-ray diffraction traces of kaolins they prepared a diagrammatic representation of kaolin clays arranged in order of crystallinity or degree of crystal perfection. In describing the crystallinity of our clays, comparison was made to the traces published by Murray and Lyons. In addition, the Brindley and Robinson indexing scheme was utilized for the X-ray traces with special attention to the resolution of peaks near the (020) and (003) reflections.

RESULTS

The X-ray trace of the Georgia kaolinite sample displays numerous, well-resolved, sharp reflections, indicating well-crystallized kaolinite (Fig. 1a). An electron micrograph shows a sharp hexagonal outline of the kaolinite platelets (Fig. 2). Kaolinite from Anna, Illinois also has a hexagonal outline (Fig. 3); however, the X-ray trace exhibits the diffusion to a band for the $K \neq 3n$ combinations (Fig. 1b). Those (hkl) reflections for which $K = 3n$ remain recognizable. The X-ray trace of the Pennsylvanian flinty clay retains reflections for combinations with $K \neq 3n$ with a relative prominence comparable with that seen on the trace of the Georgia kaolinite, but shows loss of definition among $K = 3n$ combinations (Fig. 1c). The electron micrograph shows that the platelets are irregularly shaped and nonhexagonal in outline (Fig. 4).

DISCUSSION

The data indicates a correlation of the hexagonal outline with the well-developed crystallinity of Georgia kaolinite but a lack of correlation with the crystallinity of Anna kaolinite and the Pennsylvanian flinty clay. The reason for the deteriorated state of crystalline perfection in the latter two kaolinites may be due to plastic deformation along the b-axis and strain along the a-axis (respectively). The b-axis plastic deformation apparently was sufficient to produce internal disorder while maintaining the hexagonal form of the Anna kaolinite. On the other hand, a-axis strain maintains internal order while producing a nonhexagonal outline. It is concluded that the hexagonal shape of the kaolinite plates is conditioned by some factor other than the perfection of internal order.

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NEW SPECIES OF WINTER STONEFLIES, GENUS *ALLOCAPNIA* (PLECOPTERA, CAPNIIDAE)

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ABSTRACT.—Six new species of winter stoneflies from the temperate deciduous forest area of eastern North America belonging to the genus *Allocapnia* are described as follows (with the states of occurrence indicated): *A. pechumani* (N.Y.), *A. tennessa* (Tenn.), *A. frisoni* (N.Y., Pa., W. Va.), *A. peltoides* (Ark., Okla.), *A. mohri* (Okla.), and *A. ohioensis* (Ind., Ky., Ohio). Diagnostic characters of the male genitalia are illustrated for each species.

One of the most intriguing genera of insects in eastern North America is the stonefly genus *Allocapnia*. The aquatic nymphs mature in very late autumn and early winter, and the adults emerge, mate, and lay their eggs from late November to late March, sometimes being active into early April in the northern part of their range. The genus is known only from the area occupied by the temperate deciduous forest and its northern ecotone area with the boreal coniferous forest.

Because of the restricted ranges of certain species in this genus, we think that these little stoneflies contribute valuable information to an understanding of faunal movements and dispersals associated with the glacial events of the Pleistocene. In the accumulation of material furthering these studies, several species new to science have been discovered, and six of them are described in this paper.

Unless otherwise specified, the types of all species described herein are deposited in the collection of the Illinois Natural History Survey, with a duplicate set of paratypes deposited in the Canadian National Museum.

SYSTEMATIC DESCRIPTIONS

The following new species of *Allocapnia* are small, dark members of the family Capniidae remarkably similar in superficial appearance and general characteristics to species already described. The diagnostic differences between these species are found in the shape of a few sclerites and processes at the terminal end of the body, associated with genitalic structures. Information concerning related species may be found in the detailed studies of Frison (1935, 1942), Hanson (1942), and Ricker (1952).

Allocapnia pechumani, new species

Male.—Length 5 mm. Color dark brown to blackish, the cerci and Venter light brown, the wing veins medium brown and the membrane slightly smoky. General structure typical for genus. Wings reaching only to fourth tergite. Genitalia typical of the *A. forbesi* group, Figure 1 *A, B, C*. Process of seventh tergite high, conical from lateral view, its apex cleft to form distinct lateral lobes, Figure 1 *B*. Process of eighth tergite high, its apex cleft to form a pair of wide lobes, Figure 1 *C*. Upper supra-anal process with short, sagittate apical segment.

Female.—Length of head and body 6 mm. Color and general structure similar to male. Wings extending slightly

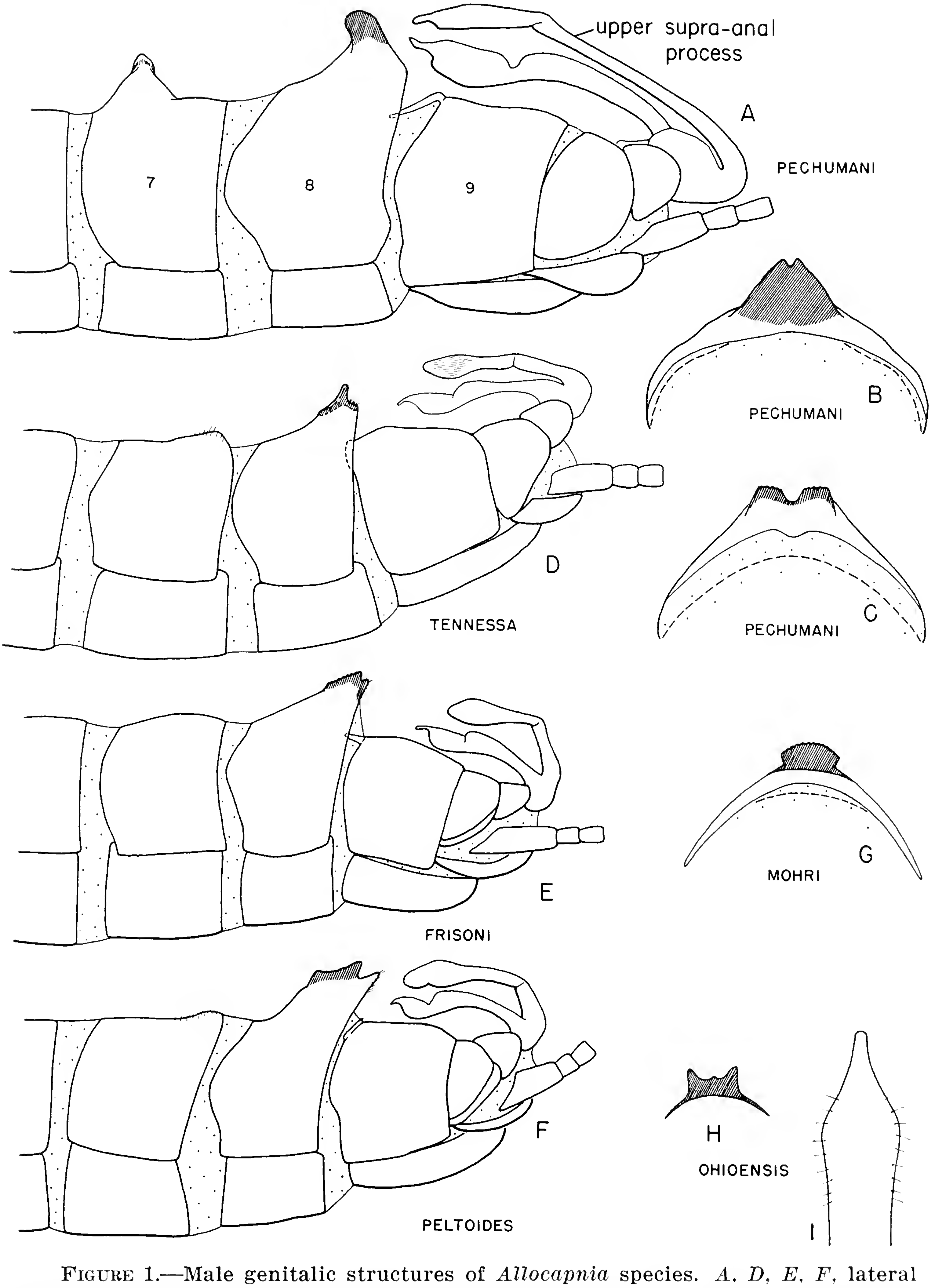

FIGURE 1.—Male genitalic structures of *Allocapnia* species. *A, D, E, F*, lateral aspect; *B*, seventh tergite, posterior aspect; *C, G, H*, eighth tergite, posterior aspect; I, tip of lower supra-anal process, dorsal aspect.

beyond the tip of the abdomen. Genital segments indistinguishable from those of *A. maria* Hanson (Ricker, 1952, Figure 116).

Holotype male, *allotype* female, and 11 male and female *paratypes*.—Starkville, Herkimer County, New York, Otsquago Creek, March 27, 1960, K. R. Chadwick. *Paratypes* — NEW YORK: Albany County, Trout Pond Creek, near Hicks Pond, Rensselaerville, April 6, 1963, L. L. Pechuman, two males; Cayuga County, Paines Creek at Route 90, Aurora, March 23, 1963, L. L. Pechuman, twelve males and four females; Greene County, tributary of West Kill, near Sprucetown March 31, 1963, L. W. All, one female; Schenectady County, small stream three miles south of junction of Route 30 and Route 159, March 19, 1957, P. H. Freytag, four males; Schuyler County, tributary of Taughannock Creek, one-tenth mile south of Mecklenburg, March 5, 1963, L. L. Pechuman, nine males and eight females; Tompkins County, Willow Creek, corner of Kraft and DuBois Roads, Ithaca, March 24, 1963, L. W. All, three males and one female; Tompkins County, Willow Creek waterfalls, five and seven-tenths miles north of Ithaca, Route 89, March 24, 1963, L. W. All, three males and one female; Tompkins County, Danby Creek, junction of Route 96 Band Van Etten Road, Danby, March 29, 1963, L. W. All, 12 males and 20 females; Tompkins County, Buttermilk Falls State Park, Ithaca, March 16, 1963, L. L. Pechuman, eight males; Esperance, April 11, 1937, H. H. Ross, one male; Fredonia, April 13, 1937, H. H. Ross, six males; Ithaca, Beebe Lake, March 11, 1959, S. E. Neff, one male; Ithaca, Beebe Lake, March 20, 1959, B. Lund, one female; Starkville, Otsquago Creek, March 27, 1960, K. R. Chadwick, ten females and three males. Deposited in the collections of the Illinois Natural History Survey, the Canadian National Museum, Cornell University, and the collection of P. H. Freytag, Columbus, Ohio.

This species is most closely related to *A. forbesi* Frison but differs in having the process of the seventh tergite cleft and occupying the middle or the front half of the tergite. From *A. maria* Hanson this species differs in the wide lobes of the process of the eighth tergite.

Allocapnia tennessa, new species

Male.—Length, color, and general structure similar to the preceding. Wings absent. Genitalia, Figure 1 *D*, having upper supra-anal process short, its apical segment as long as basal segment. Seventh tergite without a raised, sclerous process. Process of eighth tergite moderately low, its lateral aspect pointed at tip and forming a sharp angle with the posterior portion of the segment, its posterior aspect evenly arcuate, almost exactly as in Figure 1 *G*.

Female.—Length 7 mm, color and general structure similar to male. Wings of allotype reaching almost to tip of abdomen, in paratypes varying from short (reaching only to fourth tergite) to long (extending slightly beyond tip of abdomen). Seventh and eighth sternites with their mesal area fused; eighth, ninth, and tenth tergites completely and heavily sclerotized.

Holotype male, *allotype* female, and 4 male and female *paratypes*.—Three miles north of Fayetteville, Tennessee, January 27, 1958, H. H. and J. A. Ross. *Paratypes*—TENNESSEE: Triune, January 27, 1958, H. H. and J. A. Ross, eight males; two miles south of Shelbyville, January 27, 1958, H. H. and J. A. Ross, two females; five miles northwest of Shelbyville, on U.S. Alternate 41, January 26, 1958, H. H. and J. A. Ross, two males and one female; Rutherford County, Overall Creek, near south of Allisona, January 13, 1963, H. H. and J. A. Ross, two females; Marshall County, East Rock Creek, five miles north of Lewisburg, January 13, 1963, H. H. and J. A. Ross, one male; Maury County, ten miles west of Columbia, February 11, 1962, Ross and Ross, one female; Maury County, Duck River, February 11, 1962, Ross and Ross, four males and two females.

This species is a close relative only of *A. vivipara* Claassen, differing from that species in the short basal segment of the upper supra-anal process, and the less extensive fusion of the female seventh and eighth sterna.

Allocapnia frisoni, new species

Male.—Length, color and general structure similar to the preceding. Wings reaching sixth segment. Seventh tergite having no sclerous process. Eighth tergite, Figure 1 *E*, rising gradually posteriorly, the lateral aspect of its dorsal process appearing as a flat sloping area that is somewhat shield-shaped from dorsal view; below the tip of the process there is on each side a short, small, prominent projection bearing fine hairs. Both arms of supra-anal process short, the upper one having the apical and basal segments about equal in length.

Female.—Length 6 mm, color and general structure similar to male. Wings extending beyond apex of abdomen. Seventh and eighth sternites not fused, the mesal area of the posterior margin of the eighth sternite having a wedge-shaped shining area, indistinguishable at present from illustrations of *A. granulata* (Claassen) (Frison, 1935, Fig. 220).

Holotype male, *allotype* female, and 7 male and female *paratypes.*—Evansville, West Virginia, March 16, 1945, Frison et al. *Paratypes.*—NEW YORK: Cayuga County, Little Creek at Route 90, Aurora, March 23, 1963, L. L. Pechuman, one male and one female; Tompkins County, Ludlowville, Salmon Creek at bridge, Salmon Creek Road, January 19, 1963, L. L. Pechuman, two females and six males; Tompkins County, Ludlowville, Locke Creek at Salmon Creek Road, January 19, 1963, L. L. Pechuman, nine males and six females; Tompkins County, Ludlowville, Locke Creek at Gulf and Holden Road, January 19, 1963, L. L. Pechuman, one female; Tompkins County, Myers, Salmon Creek at bridge, January 19, 1963, L. L. Pechuman, one male; Tompkins County, Salmon Creek at Bridge, Myers, February 20, 1963, L. L. Pechuman, one male; Church Creek, near Lindley, March 14, 1963, L. L. Pechuman, one female; OHIO: Ash Cave, March 6, 1938, T. H. Frison, five males and six females; rock riffle, Athens, March 5, 1942, W. E. Stehr, two males; PENNSYLVANIA: small creek three miles west of Duncansville, March 10, 1958, P. H. Freytag and J. Dukes, two males and one female; WEST VIRGINIA: Horse Creek, Jaeger, February 2, 1936, J. Addair, five males and three females; Horse Creek, Jaeger, January 1, 1936, J. Addair, five males and six females; Buffalo Creek, Macomber, March 4, 1959, H. H. and J. A. Ross, one male. Deposited in the collections of the Illinois Natural History Survey, the Canadian National Museum, Cornell University, and the collection of P. H. Freytag, Columbus, Ohio.

The small, setose processes below the process of the eighth tergite indicate that of the described species of *Allocapnia* this species is most closely related to *A. granulata*. From this species *A. frisoni* differs in the flat and somewhat shield-shaped area which represents the rugose dorsal process of the eighth tergite of the male.

Allocapnia peltoides, new species

Male.—Distinguished from the preceding species only in characters of the genital segments, as follows, Figure 1 *F*: dorsal process of eighth tergite larger, its lateral aspect with the tips of the rugose area more anterior to the small haired processes than in *A. frisoni*, the dorsal aspect forming a larger shield; dorsal aspect of the upper supra-anal process almost uniform in width, not tapering at the base as in *A. frisoni.*

Female.—Indistinguishable at present from that of *A. frisoni.*

Holotype male, *allotype* female, and 1 male *paratype.*—Polk Creek, Leflore Co., Poteau, Oklahoma, Feb. 10, 1961, Ross & Ross. *Paratypes.*—ARKANSAS: Mill Creek, Scott Co., Feb. 10, 1959, Ross & Stannard, 1 male, 1 female; OKLAHOMA: 4 miles south of Lewisville, Haskel Co., Feb. 10, 1961, Ross & Ross, 1 male.

This species forms with *A. frisoni* a pair of sister species of unusual interest. It is logical to suppose that the parent of the two must have dispersed between the Appalachian region and the Ouachita region, then become separated into two isolated populations. The eastern population evolved into *A. frisoni*, the western one into *A. peltoides*.

Allocapnia mohri, new species

Male.—Length 4.5 mm. Color and general structure similar to preceding. Lateral aspect of genitalic structures as in illustrations of *A. recta* Claassen (Frison, 1935, Fig. 221). Seventh tergite without dorsal processes. Process of eighth tergite, Figure 1 *G*, moderately low, its lateral aspect gently sloping, its posterior aspect wide, arcuate, with hardly any suggestion of a shoulder at the base. Upper supra-anal process short, wide, and thin, almost foliaceous.

Female.—Indistinguishable from that of *A. recta* (Claassen) as illustrated by Frison (1935, Fig. 213).

Holotype male, *allotype* female, and 70 male and female *paratypes.*—Two miles south of Summit, Leflore County, Oklahoma, Feb. 11, 1961, Ross & Ross.

In Frison's (1935) key this species will run to *recta* (Claassen), of which it is an extremely close relative. From *A. recta*, *A. mohri* differs in the wide and arcuate apex of the process of the eighth tergite. In *A. recta* the posterior aspect of this process is much narrower and shouldered at the base.

Allocapnia ohioensis, new species

Male.—Length 5 mm. Color and general structure similar to preceding. Wings reaching fifth segment. Process of seventh tergite prominent but much smaller than that of eighth, with a suggestion of the tridentate condition. Process of eighth tergite, Fig. 1 *H*, fairly high and abrupt, posterior aspect tridentate, the middle tooth much lower than the pair of lateral teeth. Apex of lower supra-anal process, Fig. 1 *I*, tapering fairly gradually into the wider base, the tip somewhat triangular.

Female.—Seventh and eighth sternites fused, apical margin of eighth produced into a wide shiny area, projecting only a small distance beyond the lateral edge of the apical margin.

Holotype male, *allotype* female, and 10 male and 4 female *paratypes.*—Tributary of Hocking River, Coolville, Ohio, March 16, 1940, Frison et al. *Paratypes.*—INDIANA: Bryant's Creek, six miles south of Martinsville, March 25-26, 1950, W. E. Ricker, one male and three females; Center Creek, two miles south of Brooklyn, March 23, 1950, W. E. Ricker, one female; creek two miles south of Brooklyn, on Road 67, February 9, 1950, W. E. Ricker, three males: 10-Dead Creek, four miles north of Bloomington, January 5, 1950, W. E. Ricker, one male; creek northwest of Medora, February 14, 1938, T. H. Frison and C. D. Mohr, twenty-three males; Kentucky: Catlettsburg, March 10, 1959, H. H. and J. A. Ross, one male; stream northwest of Olive Hill, on Route 59, March 14, 1962, P. H. Freytag and A. B. Kunkel, one male and one female; Morehead, March 11, 1959, H. H. and J. A. Ross, thirteen males; OHIO: Ash Cave, March 6, 1938, T. H. Frison, twenty-five females and twenty-four males; Athens, Margaret Creek, March 6, 1938, T. H. Frison, one male; Road 125, nine miles east of Blue Creek, March 19, 1950, W. E. Ricker, six males; Carbondale, March 6, 1938, T. H. Frison, two males; tributary of Hocking River, Coolville, March 16, 1940, T. H. Frison, thirteen males and three females; Mount Pleasant, March 6, 1938, T. H. Frison, one female; northern branch of Sunfish Creek below Pike Lake, January 2, 1960, P. H. Freytag, twenty-two males and ten females; Turkey Creek west of Portsmouth, March 19, 1950, W. E. Ricker, one male. Some paratypes deposited in the collection of Dr. Paul Freytag, Columbus, Ohio.

This species is remarkably close to *A. indianae* Ricker, which differs from *A. ohioensis* in having a narrow and tongue-like apex of the lower supra-anal process and in having the mesal tooth of the process of the eighth tergite as high as the lateral ones. Ricker segregated many of the above paratypes from the paratype series of *A. indianae.*

Acknowledgments

We wish to give grateful acknowledgment to some sixty collaborators who have assisted us by collecting winter stoneflies during the course of this study, which is still continuing. We also wish to express our appreciation to Mrs. Alice Ann Prickett for making the illustrations.

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PROTOPLASMIC DISTRIBUTION AND PLASMODIAL FUSION IN A MYXOMYCETE *PHYSARUM POLYCEPHALUM*

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ABSTRACT.—A small plasmodium of the myxomycete, *Physarum polycephalum*, which had incorporated the isotope, P^{32}, was fused with a large migrating plasmodium of the same species. Distribution of the radioactive phosphorus at varying time intervals after fusion of the plasmodia indicated that streaming in this organism is an effective circulatory system, even during migration. The demonstration that fusable plasmodia intermix completely indicates that the lack of ability to distribute material to an area is not the direct cause of the migration phenomenon.

The primary function of rhythmic protoplasmic streaming in the myxomycete, *Physarum polycephalum*, has been assumed to be the movement of the plasmodium over substrate. While the streaming undoubtedly has other functions, a search of the literature reveals only research which has as its primary concern the relation of the protoplasmic streaming (or motive force) to plasmodial movement (Kamiya, 1953). Normally, migration does not occur when *P. polycephalum* is grown upon an adequate medium, such as after the method of Daniel and Rusch (1961). However, as food material becomes exhausted, the plasmodium begins migration. It has also been observed that when the plasmodium grows off of oat flakes upon which it has been cultured, it begins to migrate. Could it be that the failure of materials to be distributed from the food source to the periphera of the plasmodium is a factor in initiation of migration? A second possible function would be that of oxygen transport in the organism. Oxygen needs in laboratory cultures are probably met by simple diffusion, but in natural conditions parts of the plasmodium which are entrenched in decaying wood are undoubtedly subjected to very low partial pressures of oxygen. While the organism is known to tolerate tensions of oxygen as low as 3mm Hg (Kitching, 1940), trace amounts of oxygen are essential for continued survival (Loewy, 1950). All of these considerations suggested the following question: How effective is the shuttle type streaming in the distribution of components throughout the plasmodium of the acellular slime molds?

The plasmodia of *P. polycephalum* are capable of rapid fusion with one another. This peculiar property prompted another question. To what extent is one plasmodium itself an individual from another? When a small plasmodium is fused to a larger one, does it remain together as a unit within the larger plasmodium or is it distributed by the larger one literally as part of itself?

Finally, what is the effectiveness of distribution of a particular component by protoplasmic streaming during movement of the plasmodia? It is easy enough to assume that distribution of materials may occur while the organism is not migrating, but what happens when the organism is advancing at a rate of 3 to 4 cm/hr, as has been previously reported by Anderson (1963)?

To obtain answers to some of the above questions, a labeled plasmodium (one which has incorporated the isotope P^{32}) and a non-labeled plasmodium were allowed to fuse and the distribution of the isotope in the unlabeled plasmodium was followed as a function of time.

Materials and Methods

The organism, *P. polycephalum*, was grown after the method of Camp (1936) on rolled oats. The isotope P^{32} was incorporated into a growing culture by mixing with oats fed to the myxomycete. Both the labeled and unlabeled plasmodia were subcultured from plasmodia obtained from Dr. D. P. Rogers, of the University of Illinois. Previous work (Anderson, 1963) has shown that unidirectional migration of plasmodia on an agar surface can be obtained by outlining the projected path with Parafilm, a product of the Marathon Co. The larger unlabeled plasmodium was placed at one end of a lucite tray (90 cm long, 30 cm wide, and 5 cm deep) which was filled with 3% agar to a depth of one cm. A two inch perimeter of the agar surface was overlain with Parafilm. Since the plasmodium will not migrate onto the Parafilm, it migrated unidirectionally down the tray. After the large unlabeled plasmodium had migrated unidirectionally a distance of 19 cm, 71.4 mg of a plasmodium, which had incorporated P^{32} to the extent of 50 counts per minute per

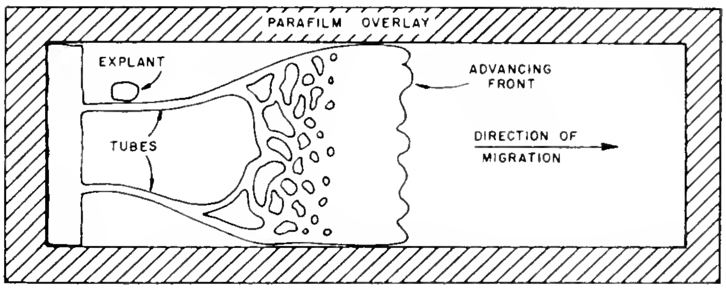

FIGURE 1.—Diagram of experimental set up. Explant of a small labeled plasmodium which had incorporated P^{32} was put in apposition to the tube of a large unidirectionally migrating unlabeled plasmodium nineteen centimeters behind the advancing front.

milligram of wet weight, was put in apposition to a large tube of the migrating plasmodium (Figure 1). Counting was performed with a General Scaler Ratemeter, Nucleonic Corporation of America, Model RCR2, with an end window tube. For all counts the tube was held at a fixed distance of 1.5 cm from the agar surface. Counts were taken at various distances along the left side of the organism on which the tagged explant had been placed. In one instance (at 3 hrs and 50 min), the arm holding the counting tube was extended to perform a series of counts on the right side of the plasmodium.

Results and Discussion

Within an hour after fusion of the P^{32} labeled transplant with the larger non-labeled migrating plasmodium, distribution of P^{32} could be detected throughout the organism (reading 2 of Table 1). Distribution of material in an anterior-posterior direction would be expected since this is the axis of migration and the direction of orientation of the large tubes. Detection of the isotope along the edge of the plasmodium opposite to the site of the explant indicates that

TABLE 1.—Distribution of P^{32} in a Migrating Plasmodium as a Function of Time and Distance Posterior to Advancing Front.

Reading No.	Elapsed time (hrs:min)	Side of explant reading taken	Distance leading edge had migrated (cm)	Counts per minute corrected for background[a]				
				at leading edge	10 cm back from leading edge	20 cm back from leading edge	30 cm back from leading edge	40 cm back from leading edge
			19.0	(Tagged explant put in place)				
1........	0:20	Left	22.0	0.0[b]	4.0[b]	.....	.....	....
2........	0:50	Left	23.0	5.0	33.0	.....	.....	....
3........	1:10	Left	24.0	1.0	15.0	.....	.....	....
4........	2:15	Left	27.0	4.0	12.0	42.0	.....	....
5........	3:00	Left	29.0	20.0[b]	33.0	141.0	.....	....
6........	3:20	Right	30.0	53.0[c]	65.0	157.0	.....	....
7........	3:50	Left	31.0	40.0	102.0	87.0	135.0	....
8........	10:40	Left	52.0	84.0	86.0	77.0[c]	71.0	77.0

[a] Unless otherwise indicated experimental counts were for two minutes.
[b] Counting period was one minute.
[c] Counting period was three minutes.

there is considerable distribution laterally (reading 6 of Table 1). These findings demonstrate that the shuttle type streaming of *P. polycephalum* might very well serve to transport oxygen or some other nutrient even while the organism is moving over a substrate or in the intersticies of decaying wood.

It should be noted that during the experiment the large plasmodium was migrating at the rate of 3 cm/hr. Since the agar surface on which it was migrating was 20 cm wide, this meant that the plasmodium was increasing its surface area at the rate of 60 cm^2/hr. A fixed area was counted. The effect of the migration, therefore, is to dilute the number of counts by increasing the overall area and volume.

The results indicate that the distribution of the isotope to the advancing front is essentially the same as to other areas. This implies that the lack of ability to distribute material to an area (that is, the advancing front) could not be involved in the migration phenomena.

It is assumed in this experiment that some of the isotope in the explant had been incorporated into nuclei and other cellular components. Therefore, the distribution of isotope in the migrating plasmodium may be taken as an index of the distribution of nuclei and cytoplasm from the smaller plasmodium throughout the matrix of the larger. Thus the experiment shows there is a complete intermixing of fusable plasmodia.

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Discussions with Drs. John W. Daniel and H. P. Rusch of the McArdle Memorial Laboratories, Madison, Wisconsin, and Dr. W. Ross

Ashby of Departments of Electrical Engineering and Biophysics, University of Illinois, led the authors to formulate this experiment.

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EFFECT OF CONCENTRATION OF ADDED CHELATES AND SALTS UPON SURVIVAL OF *ESCHERICHIA COLI* AND *SHIGELLA SONNEI* IN LAKE MICHIGAN WATER

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ABSTRACT.—Sodium thiosulfate in a concentration of 30 mg/100 ml is a protective agent for survival of populations of *Shigella sonnei* and *Escherichia coli* in samples of toxic Lake Michigan water. EDTA is more or less protective according to the concentrations used.

This report is concerned with the effect of tetra-sodium salt of ethylene diamine tetraacetic acid (EDTA), sodium thiosulfate, iodate and phosphate upon the survival of *Shigella sonnei* and *Escherichia coli* in Lake Michigan water. The study of the effect of inorganic ions upon survival of bacteria in lake water is part of an extensive program that has been in progress for about ten years. As the result of this work, we have evidence that Lake Michigan water, with respect to toxicity toward *E. coli* and its relatives, may be characterized by four types, (1) high toxicity and low stability, (2) lower toxicity but greater stability, (3) incipient toxicity which is activated by heat and (4) no toxicity, even when heated at 100° C for ten minutes. In type (1) water, 50 thousand to 100 thousand test bacteria may be killed within one to two hours.

Noble and Gullans (1955) established that coliform bacteria decreased in numbers when the untreated Lake Michigan water was stored at temperatures ranging from 5° C to 30° C. In all months of the year, there was a significant loss in coliform numbers; the losses were especially large in the summer months. On several occasions there was significant loss within one or two hours. They also established that $Na_2S_20_3$ furnished partial protection when added to the water samples in the concentration of 19 mg per ml. Shipe and Fields (1956) used the chelating agent, versene, EDTA, to eliminate the effects of heavy metal ions in Tennessee River waters. Johannessen (1957) reported that iodate was responsible for the loss of coliform bacteria in New Zealand sea water.

MATERIALS AND METHODS

Untreated Lake Michigan water collected directly from the incurrent stream at the Chicago 79th Street water filtration plant was brought to the laboratory and sterilized by filtration through Selas, sintered glass or membrane filters. The filtered lake water was placed in chemically clean pyrex bottles. They were washed at least 10 times in tapwater and three times in distilled water. The bottles were covered with aluminum foil during sterilization for three hours at 165°C in an electric oven. Before use, these aluminum films were replaced with cotton stoppers which had been sterilized in an autoclave. This precaution was exercised to prevent the presence in the bottles of any toxic fumes from heated cotton. The lake water pH was 7.8 to 8.0 and the pH was adjusted with 0.1 N HCl or 0.1 N NaOH after the addition of any agent. Distilled water was thrice distilled in glass from a weak permanganate lake water solution. The distilled water was buffered with 0.001 M potassium phosphate to give a pH of 7.8.

The *S. sonnei* and *E. coli* cells were cultured for 24 hours in heart infusion broth at 37°C. The cells were centrifuged, washed three times and suspended in 0.02 M potassium phosphate buffer at pH 7.0. Suspensions of these cells were brought to an optical density of 1.0 in sterile buffer and 1 ml of the suspension was inoculated into test bottles containing 99ml sterile lake water. One pair of bottles contained a 1 to 100 dilution of the suspension; another pair contained a 1 to 10,000 dilution of the suspension. These latter bottles had about 60 to 80 viable bacteria per ml when a 1-10 dilution was plated at zero time in heart infusion agar. The zero time count was determined for the test organisms in every experiment. The bottles with the higher concentrations of cells were not sampled except for time studies with highly toxic waters. That is, if we suspected that all the bacteria in the bottles with the 10^{-4} dilution would be killed, we would then determine the number of viable cells in the bottle with the 10^{-2} dilution.

In studies with sodium thiosulfate, the concentrations tested ranged from 5 mg/100 ml to 1000 mg/ml. Thirty mg/100 ml was the minimum effective concentration. Noble and Gullans (1955) used essentially the same concentration in their study which established that sodium thiosulfate acts as a protective agent for coliform organisms in untreated lake water.

Results and Discussion

In a series of ten experiments, sodium thiosulfate afforded an average protective value of 65% when added in a concentration of 30 mg/100 ml to highly toxic lake water—those waters in which there was over a 95% loss of *Shigella sonnei* within 24 hours. The range of protection varied from 40% to 95%.

When the work of Noble and Gullans (1955) was recalculated on the basis of per cent protection afforded coliforms using the MPN (Most Probable Number) method, the average protective value for 215 experiments was 41%. The amount of protection supplied during each month of the year is given in Table 1. These results are the averages for the effect on toxic and non-toxic lake waters while the average cited in the previ-

Table 1.—Protection Afforded Coliform Bacteria by $Na_2S_2O_3$ in Samples of Lake Michigan Water When Stored for 18 Hours at 5° C. Calculated from Noble (1955). J. Bacteriol. 55: 249.

Month	Number of Samples	Protection Afforded %
January	18	30
February	19	40
March	15	34
April	17	29
May	14	10
June	17	10
July	20	80
August	23	40
September	19	58
October	20	60
November	18	58
December	15	44

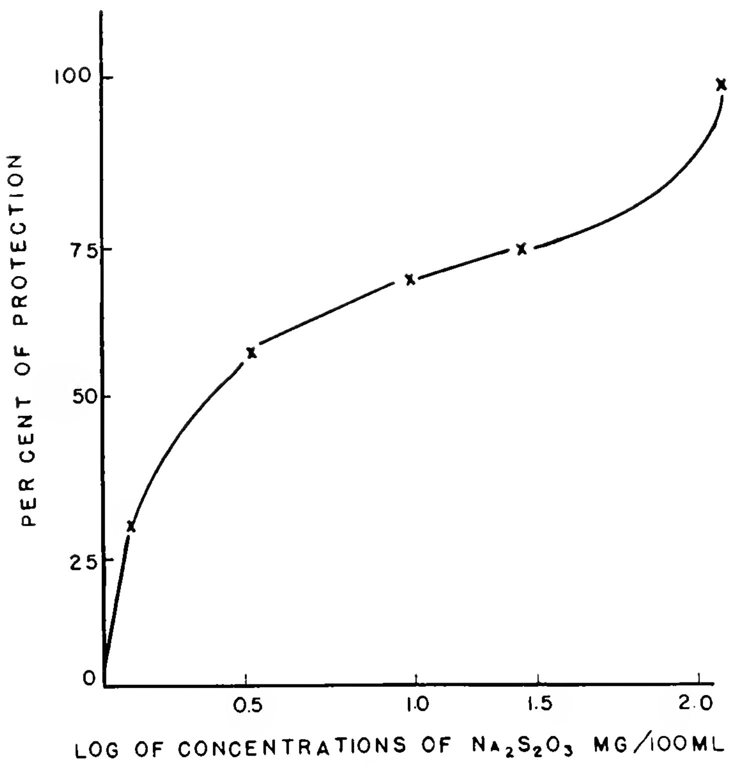


FIGURE 1.—Effect of concentrations of thiosulfate upon protection afforded *Shigella sonnei* when stored in toxic lake water (8-13-57 lake water).

ous paragraphs was for toxic water only in relation to the survival of *S. sonnei.* The separate populations of *E. coli* and *S. sonnei* responded to thiosulfate in essentially the same manner as did the mixed and complex populations of bacteria known as coliforms.

Results of a typical experiment with varying concentrations of sodium thiosulfate are given in Figure 1. In the intermediate range 0.10 mg/ml to 0.30 mg/ml the difference in concentration did not appreciably effect the amount of protection afforded by the salt. However, with higher concentrations the protection afforded by 1.0 mg/ml was nearly 100%.

Shipe and Fields (1956) attributed their protection of coliform organisms in Tennessee River waters to the chelation effect of EDTA upon the toxic heavy metals. In experiments with EDTA in Lake Michigan water the agent was used in concentrations ranging from 10^{-1} to 10^{-8} g/ml. Invariably the 10^{-1} concentration was toxic, but the 10^{-2} concentration was much more protective than were the concentrations of 10^{-3} and 10^{-4}. The 10^{-5} concentration was more protective than the higher concentration of 10^{-3} and 10^{-4} and the lesser concentrations of 10^{-7} and 10^{-8}. Studies with EDTA in triply distilled water gave results similar to those in Lake Michigan water. In these particular experiments both the distilled water and the lake water were highly toxic for the test bacteria without any added agent.

When the residual population numbers are plotted again EDTA concentrations, a bimodal curve is obtained (Fig. 2). Since the distilled water came from chemically clean glass, the concentration of heavy metals in this water is very low. The lake water with a pH of 8.0 would likewise have a low concentration of heavy metal ions. Hence the protective effect of EDTA is due to some

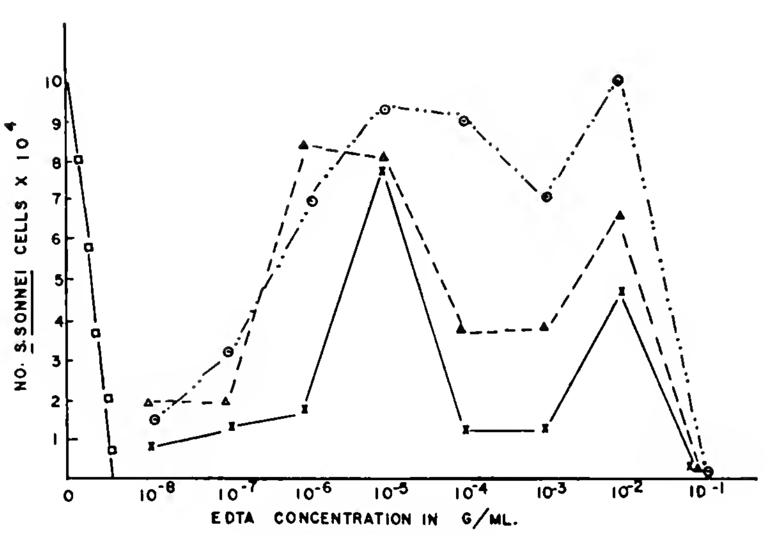


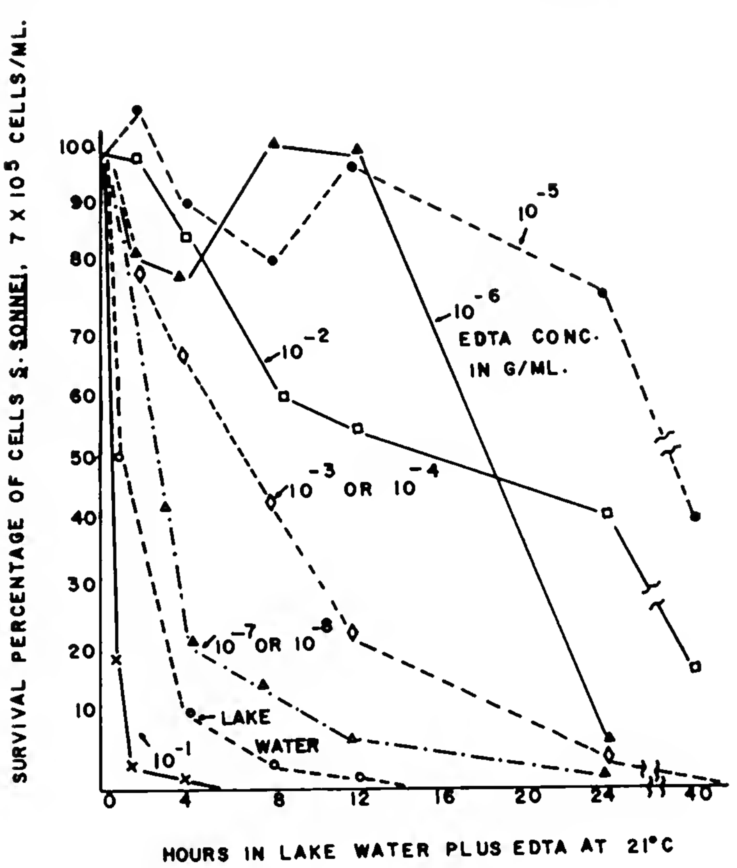
FIGURE 2.—Effect of incubation time and EDTA concentration upon survival of *S. sonnei* in lake water and in distilled water. Symbols: circle, dot and dashed line, 5 hours incubation; triangle and dashed line, 10 hours incubation; X-mark and line, 24 hours incubation; and square and line, distilled water 24 hours.

mechanism other than the chelation of heavy metal ions inherent in the water.

What is the explanation for the bimodal curve with differing concentrations of EDTA? The answers are not known, but some tentative hypotheses will be presented.

The 10^{-1} concentration is obviously toxic to the bacterial cells. The protection provided by the 10^{-2} concentration of EDTA, may be explained by assuming that: (a) the agent in some manner acts upon the surface of the cells by binding some inhibitory ions and/or (b) sufficient adsorption of EDTA by cells to block the entrance of the lake water toxic factor. We have no proof for either hypothesis. Why the concentrations of 10^{-3} and 10^{-4} are less protective than either of the 10^{-2} or the 10^{-5} concentrations is not known. The nearly equal protection provided by the 10^{-2} and 10^{-5} concentrations may be attributed to the chelation of different types of toxic substances. Shipe and Fields reported that optimum concentrations of EDTA for chelation of the heavy metals, zinc and copper, were 10^{-3} and 10^{-5} respectively. This chelation of the heavy metals prevented the loss of the bacteria in the Tennessee River waters containing these toxic heavy metal ions.

FIGURE 3.—Effect of EDTA concentration upon survival of *S. sonnei*.



In an experiment with the survival of *S. sonnei* in lake water, the concentration 10^{-6} was as protective as 10^{-5} for the first 12 hours. For longer periods of time it was much less effective (Fig. 3). The absence of protection in both distilled and lake water for the weaker concentrations 10^{-7} and 10^{-8} is obviously due to the low concentration of EDTA.

As indicated in Table 2, there was protection against the toxic factor

TABLE 2.—Protective Effect of Iodate Upon Toxic Factor in Lake Michigan Water.

Suspending Medium	Number of *Shigella sonnei* x 10^3 per/ml of Lakewater or Lakewater Plus Iodate.	
	Zero Time	After 24 hr Storage at 21°C.
Lake Water (10–15–57)	85, 100	0, 0
Lake Water Plus Iodate 0.01 ug/ml	106, 88	60, 70
0.02 ug/ml	150, 73	52, 42
0.03 ug/ml	92, 100	30, 24
0.04 ug/ml	128, 85	43, 23

in Lake Michigan water when the iodate concentration was as low as 0.01 ug/ml. The results given in this table are the averages of four carefully controlled experiments. However, Johannessen (1957) reported that iodate in the concentrations of .02 ug to .04 ug/ml was toxic to coliform in sea water. The attempts to detect any iodate in Lake Michigan water using the sulfamic acid titration procedure employed by Johannessen were negative.

Allen, Pasley and Pierce (1952) reported that 0.003 M phosphate was the most desirable concentration for the storage of *E. coli* and related organisms. Straka and Stokes (1957) indicated that phosphate buffer used as diluent in dilution bottles permitted the loss in some instances of as much as 20% to 30% of the bacteria within 20 minutes and as much as 80% loss within an hour.

In the lake water studies it was desirable to compare the survival of numbers of bacteria in well water with those in lake water. The pH of the well water was adjusted to that of the lake water with 0.003 M phosphate. The effect of the same concentration of phosphate in lake water was determined on several different sampling days. In general, the results in lake water for *S. sonnei* and *E. coli* were similar. In tests with phosphate (0.001 M and 0.005 M) in lake water afforded some protection; there was about a 50% loss in 24 hours. In the weaker phosphate concentration, less than 0.001 M, there was a 66% loss. However, this is probably not a significant difference. In the studies with triply distilled water from glass, the survival for *S. sonnei* with or without 0.001 M phosphate were essentially the same, that is, about a 50% loss within 24 hours. In both of these conditions there was more loss than with the parent lake water from which the distilled water was prepared. *Escherichia coli* appears to be more sensitive to distilled water than does *S. sonnei*, and phosphate is protective for *E. coli* in distilled water. These data are given in Table 3. They are at variance with the work reported by Straka and Stokes with the effect of phosphate in dilution solutions. In experiments with lake water, the water was sterilized by filtration after the addition of the phosphate. In the Straka and Stokes studies, the phosphate was added to the diluent prior to sterilization in an autoclave. Finkelstein and Lankford (1957) have indicated that phosphate at pH 8.0 induces toxicity upon being autoclaved, especially in the presence of sugars.

Summary

In the studies of the survival of populations of *Shigella sonnei* and *Escherichia coli* in Lake Michigan water, it was determined that sodium thiosulfate in a concentration of 30 mg/100 ml was a protective agent in samples of toxic lake water. In nontoxic lake water, it produced no effect. Iodate in the concentrations used was not toxic to these test bacteria nor could iodate be detected in Lake Michigan water.

The chelating agent EDTA, was highly protective at concentrations of 10^{-2}, 10^{-5}, and 10^{-6} g/ml, but it was less protective at concentrations of 10^{-3}, 10^{-4}, 10^{-7} and 10^{-8}. At the 10^{-1} concentration, EDTA was highly

TABLE 3.—Influence of Phosphate Upon Survival of *E. coli* and *S. sonnei* in Lake Water and Triply Distilled Water. Temperature of Storage 21° C; pH of Lake Water and Distilled Water 7.8. Multiply Colony Counts by 10^3.

	Lake Water		Lake Water plus Phosphate						Lake Water		Triply Distilled Water		Triply Distilled Water Plus 0.001 M. PO_4	
			0.001 M PO_4		0.005 M PO_4		0.0001 M PO_4							
	Time 0	Hr 24	Time 0	Hr 24	Time 0	Hr 24	Time 0	Hr 24	Time 0	Hr 24	Time 0	Hr 24	Time 0	Hr 24
E. coli														
Avg. No. of Colonies	64	39	71	97	76	29	64	16	52	37	62	2	50	57
No. of Tests	40		36		16		16		14		14		14	
S. sonnei														
Avg. No. of Colonies	59	40	70	94	68	32	71	24	58	42	55	20	56	33
No. of Tests	46		36		18		16		14		14		12	

toxic to the bacteria. Since the results were obtained in both triply distilled and lake water, its action is other than the chelation of the heavy metals inherent in the waters. Potassium phosphate, 0.001 M, is somewhat protective to *S. sonnei* and *E. coli* in lake water and is protective to *E. coli* in distilled water. Phosphate in 0.005 M and 0.0001 M concentrations is neither protective nor especially toxic.

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THE COMPARATIVE EFFECTS OF DESICCATED PARROT FISH THYROID GLAND AND SYNTHETIC THYROXIN ON THE RESPIRATORY METABOLISM OF WHITE MICE

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Abstract.—Desiccated parrot fish thyroid extract, though questionably calorigenic in fish, has a finite calorigenic effect paralleling that of synthetic thyroxin in mice. The dosages of hormones used in this experiment are apparently pharmacologically effective.

Recent literature concerning the physiology of the thyroid gland in fish reveals that its function is not clearly understood (Pickford and Atz, 1957; Gorbman and Bern, 1962).

The literature does establish that the thyroid hormones of fish are chemically similar to those of other vertebrates. Furthermore, biochemical function in the fish thyroid closely parallels biochemical function in the mammal, although details of the way in which thyroxin enters the chain of biochemical reactions are not entirely clear even for mammals. However, investigators have not always been careful to separate responses to massive effective doses of thyroid hormones from responses to small effective doses of thyroid hormones, thereby providing misleading information as to thyroid function in the species receiving the hormones. Furthermore, it seems most likely that in vertebrates in general, species variation is related to a plurality of tissue responses rather than to a plurality of thyroid hormones.

Data about the effect on fish or other species of vertebrates of thyroid extracts derived from the glands of fish are scarce, owing in part to the unencapsulated nature of the gland in most species. Sembrat (1927) and Mathews and Ash (1951) have used fish thyroids to induce premature metamorphosis in frog tadpoles. We have had some success in repeating the latters' experiments, the preparation of parrot fish thyroid gland being the same one used in the experiment detailed below. Smith and Mathews (1948) reported that parrot fish thyroid increased oxygen consumption in white grunts, *Haemulium plumieri,* over 15 cm in length. However, this work was questioned by Matty (1957) who found that surgical thyroidectomy of the encapsulated gland of the Bermuda parrot fish, *Pseudoscarus gaucamaia,* did not alter its oxygen consumption. Injection of L-thyroxin or an extract of parrot fish thyroid gland did not change the standard rate of oxygen consumption in intact animals. To our knowledge the work of Smith and Brown (1952) and Matty (1954) are the only reports of a calorigenic effect of fish thyroid extract in a mammal.

One of us (R.G.B.) has been studying thyroid function in goldfish, *Carassius auratus,* using both synthetic thyroxin and triiodothyronine as well as desiccated parrot fish (*Pseudoscarus guacamaia*) thyroid. Inasmuch as synthetic thyroid hormones produced marked growth and morphogenic responses in goldfish, while desiccated parrot fish thyroid failed to elicit any kind of response in goldfish, an experiment was conducted to test the efficacy of the parrot fish thyroid preparation used. Results of the experiment are reported in this paper.

Materials and Methods

Eleven, adult male white mice, chosen from a stock conditioned to laboratory life for several weeks prior to the start of the experiment, were toe-clipped for individual identification. After random assignment of three animals to a saline control group, four to a group to receive sodium L-thyroxin pentahydrate (Mann Research Laboratories Inc.), and four to a group to receive desiccated parrot fish thyroid, determinations of their relative oxygen consumption were taken by the method of Lauber (1962). The term "relative" is used since the absolute value of the quantity of oxygen consumed is not recorded on the kymograph drum used.

Since conditions remained reasonably constant throughout the experiment, any inherent error produced by the apparatus should be constant. The temperature within the animal test chamber was maintained at 29 ± 1° C. The test chamber was covered with a dark cloth and no significant differences were obtained in repeating observations on animals tested twice within an hour.

All determinations were made between mid-morning and early afternoon, after which the animals were fed a standard pelleted diet. Food, but not water, was removed from the cages during mid-evening at least 12 hours prior to the next series of observations.

The arithmetic means of the last three of four pre-experimental 10 minute determinations for each mouse were used as "basal" rates (Table 1). In this way all animals served as their own standards of comparison in addition to having the saline injected controls available as common standards during the actual experiment. Values in Table 1 represent kymograph readings in mm/gm body weight of mouse per 10 minutes. Data were tested for significance using the H test of Tate and Clelland (1957, pp. 109-111) with the level of significance, alpha (α), chosen as 0.05.

The parrot fish glands were ground to a powder and the powder passed through No. 25 silk bolting cloth. Both parrot fish thyroid powder and thyroxin were dissolved in 0.1N NaOH, neutralized with 0.1N HCl and diluted to the desired concentration in buffered saline adjusted to pH 7.2. Thyroxin (3.2 μg/gm body weight) or parrot fish thyroid (260 μg/gm body weight) was injected intra-abdominally. All animals including controls received 0.06 cc of fluid per gm body weight. Relative oxygen consumption of all animals was determined on days 1, 2, 3, 4, 5, 7, 10, and 12 following the single injection and all animals were sacrificed using ether, and carefully necropsied on day 13.

TABLE 1.—Mean Basal and Post Injection Relative Oxygen Consumption, in Millimeters per Gram Body Weight per Ten Minutes, of Individual Mice Treated with Thyroid Hormones

Treatment	Mean Basal	Days After Injection							
		1	2	3	4	5	7	10	12
Saline..............	.575	.599	.583	.571	.589	.590	.572	.568	.586
	.498	.540	.520	.550	.511	.491	.477	.476	.508
	.522	.545	.532	.552	.515	.534	.518	.514	.499
Parrot Fish Thyroid.	.484	.514	.495	.582	.698	.710	.601	.537	.473
	.492	.502	.553	.552	.727	.635	.746	.493	.487
	.432	.540	.617	.811	.624	.732	.589	.484	.451
	.522	.541	.642	.881	.674	.814	.647	.584	.511
L-Thyroxin.........	.480	.507	.749	.813	.725	.761	.620	.593	.476
	.492	.592	.704	.667	.558	.593	.589	.415	.509
	.506	.525	.681	.684	.610	.715	.680	.471	.500
	.432	.556	.643	.750	.589	.605	.624	.454	.495

RESULTS

The relative oxygen consumption of treated mice is summarized in Table 1. Differences for days 1, 7, 10, and 12 are not statistically significant. Differences for days 2, 4, and 5 are significant and for day 3 are highly significant.

Responses to thyroxin and fish thyroid extract were quite similar, in both magnitude of change and duration of change. The onset of responses lagged slightly in the mice treated with parrot fish thyroid.

DISCUSSION

The presence of a calorigenic effect of a teleost thyroid extract injected into mice parallels the finding of Smith and Brown (1952) for teleost thyroid extract injected into the laboratory rat, and of Matty (1954) for shark thyroid extract injected into laboratory rats.

Necropsy findings in rats treated with fish thyroid extract have not been reported. It was surprising to find a definite ulceration of the stomach in one of the four animals in each of the experimental groups, but no visible changes in the visceral organs of members of the control group. Two of the remaining three animals in each group showed signs of developing ulcers of the stomach. Hair erection was noted immediately after injection in all groups. Turner (1955, p. 161) states that erection of hair is a sign of "emergency function" mediated by the sympathoadrenal system. Hair erection disappeared in a few hours in control animals, but persisted approximately 24 hours in the experimental animals.

No sign of puncture of vital organs was evident in any animal and the ulcerations of the stomach wall were interpreted as part of the General Adaptation Syndrome, suggesting that our dosages of hormones were pharmacologically effective. Inasmuch as the dosages used in the present experiment with mice were comparable on a body weight basis to those used in rats by Smith and Brown (1952), it appears likely that doses used by them were also pharmacologically effective. Heming and Holtkamp (1953) considered anything over 1.5 $\mu g/gm$ body weight per day of thyroxin (Smith, Kline, and French Lab. Philadelphia, Pa.) pharmacologically effective in rats.

Acknowledgments

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TWO LATE WOODLAND ARCHAEOLOGICAL SITES IN LAKE COUNTY, ILLINOIS

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ABSTRACT.—Two Late Woodland Sites in Lake County, Illinois are desecribed. The Beake Site, consisting of burials and pits, was occupied by Late Woodland and Upper Mississippian peoples, but at different times. The Half Day Club Site, consisting of burials and pits, was occupied by Upper Mississippian peoples who were in contact with Late Woodland peoples.

Two Indian village sites, the Beake Site and the Half Day Club Site, in Lake County, Illinois had been known to Illinois archaeologists for several years. Both sites have been destroyed by gravel operators. This report brings together the earlier information and data salvaged during the destruction of the sites.

THE BEAKE SITE

The Beake Site (IAS No. L-3) was located in the Southwest 1/4 of Section 27, Township 45 North, Range 11 East, south of State Highway 20 (Belvidere Road) and north of the first intermittent stream on the west bank of the Des Plaines River, approximately five miles west of the City of Waukegan in Lake County in northeastern Illinois. The area excavated was on the floodplain of the river (Figure 1). Burials from the site were reported earlier by Young, Wenner and Bluhm (1961). The author is grateful to Mr. David J. Wenner, Jr. who furnished the notes for the following report.

The scant surface collection from the site indicates that it was not intensively occupied by the Indians. But, as the site was located in a gravel pit, it is possible that some materials were removed along with the gravel. The archaeological remains discussed here consisted of a series of twelve pits or features which were partly removed by the gravel operations. In some cases half or less of some of them remained.

All the features had soil which was hard and compact and were set in a matrix of soft and loose stratified river sand and gravel. Most were irregularly oval or round in shape with flat bottoms. Charcoal was found scattered near the bottoms of some pits and may have been the result of partly carbonized roots or human activity. Because of the scantness of the artifactual material, the main importance of the site lies in the size of the features.

Artifacts. The ceramic remains consisted of fourteen body sherds, which were divided into the following types: ten Lake Michigan Ware, and four Langford Plain (Bennett, 1945, p. 80-81 and Griffin, 1946, p. 19-20). The Lake Michigan sherds were found in features 1, 3, 4, 7, 8 and 10. The Langford Plain sherds were found on the surface and in features 1, 6 and 9.

The stone artifacts consisted of two random flake scrapers of cream-

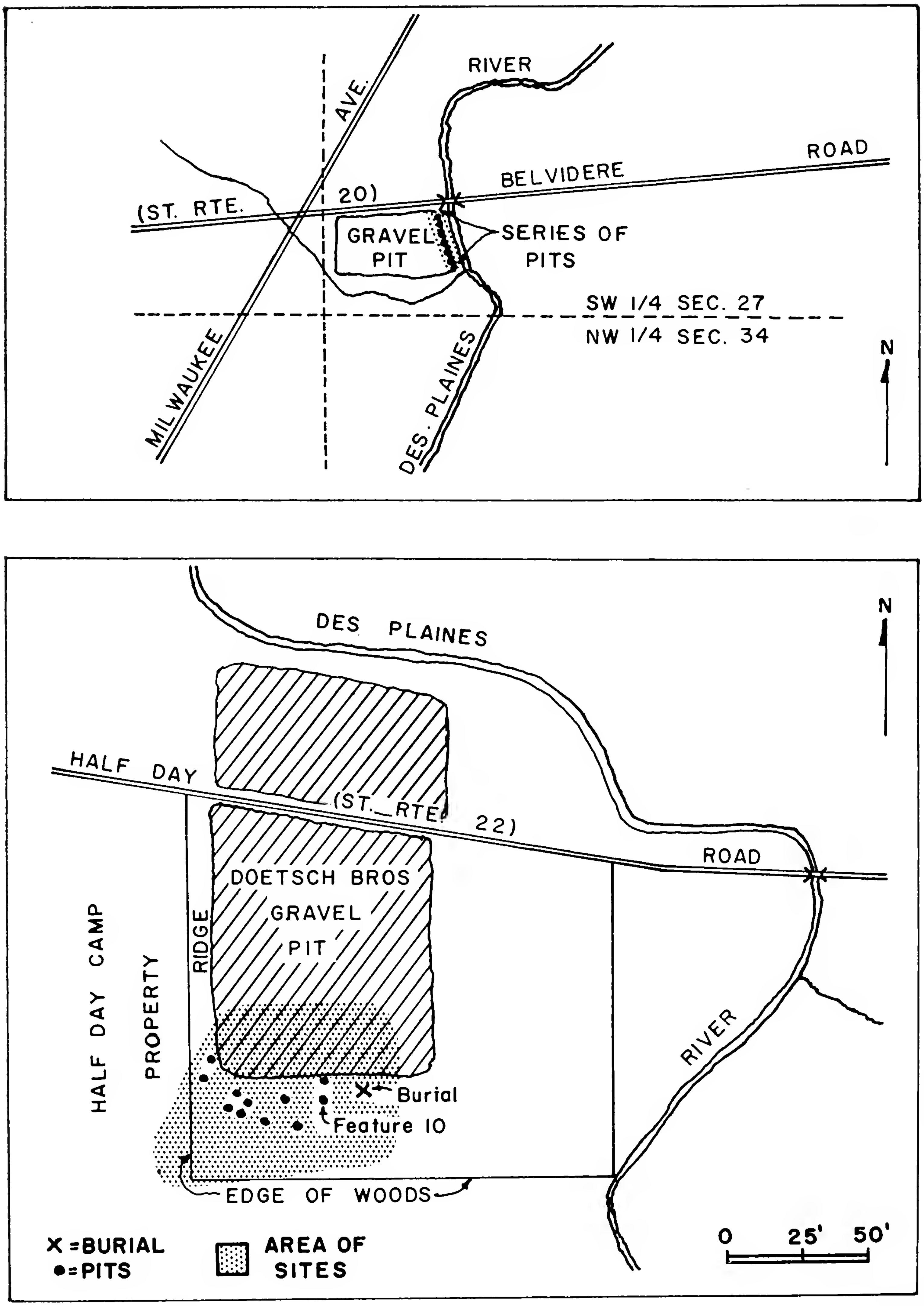

Fig. 1.—Map of site IAS L-3, the Beake Site (above), and site IAS L-2, the Half Day Club Site (below) in Lake County, Illinois.

colored chert and three projectile points. The scrapers were found in features 1 and 3. The projectile points were surface finds. One point is a triangular Mississippian type, 2.4 cm long and 1.8 cm wide with a straight base and sides. Another is similar to Late Woodland types, being corner-notched with a convex base, 2.4 cm long and 1.4 cm wide. The last point is archaic-like, lanceolate, stemless, straight based, 9.0 cm long 3.2 cm wide, and is probably associated with the earlier occupation of the site (Young, Wenner and Bluhm, 1961, p. 21).

Non-artifactual Remains. The non-artifact remains consisted of the following items: unidentifiable bone in features 1, 3, 4, 9 and 10; shell fragments from features 2 and 4; snails were present in pits 1 and 3; chert chips in features 1 (1), 2 (6), 3 (6), 4 (9) and 9 (1). Nine chert chips were found eight inches below the surface of feature 2.

Features. All the features, except number 5, were cache pits and all were flat bottomed, except numbers 1, 3, 4, 5 and 6, which were globular in form. Charcoal was heavily concentrated in features 1 and 7, present in small quantities in 2, 4, 8, 9 and 11, but absent from pits 3, 5, 6, 10 and 12. The pits were located about one foot below the surface, except number 5, which was just below the two inch humus line (Figure 2). The range of size of the pits is as follows: .65 to 7.5 feet wide (average 3.3) and .6 to 3.4 feet deep (average 2.2). The actual shape of the pits horizontally cannot be determined as the majority of the pits had been partially removed before salvage, but it is assumed they were round or oval from the semi-circular shape which was noted when the fea-

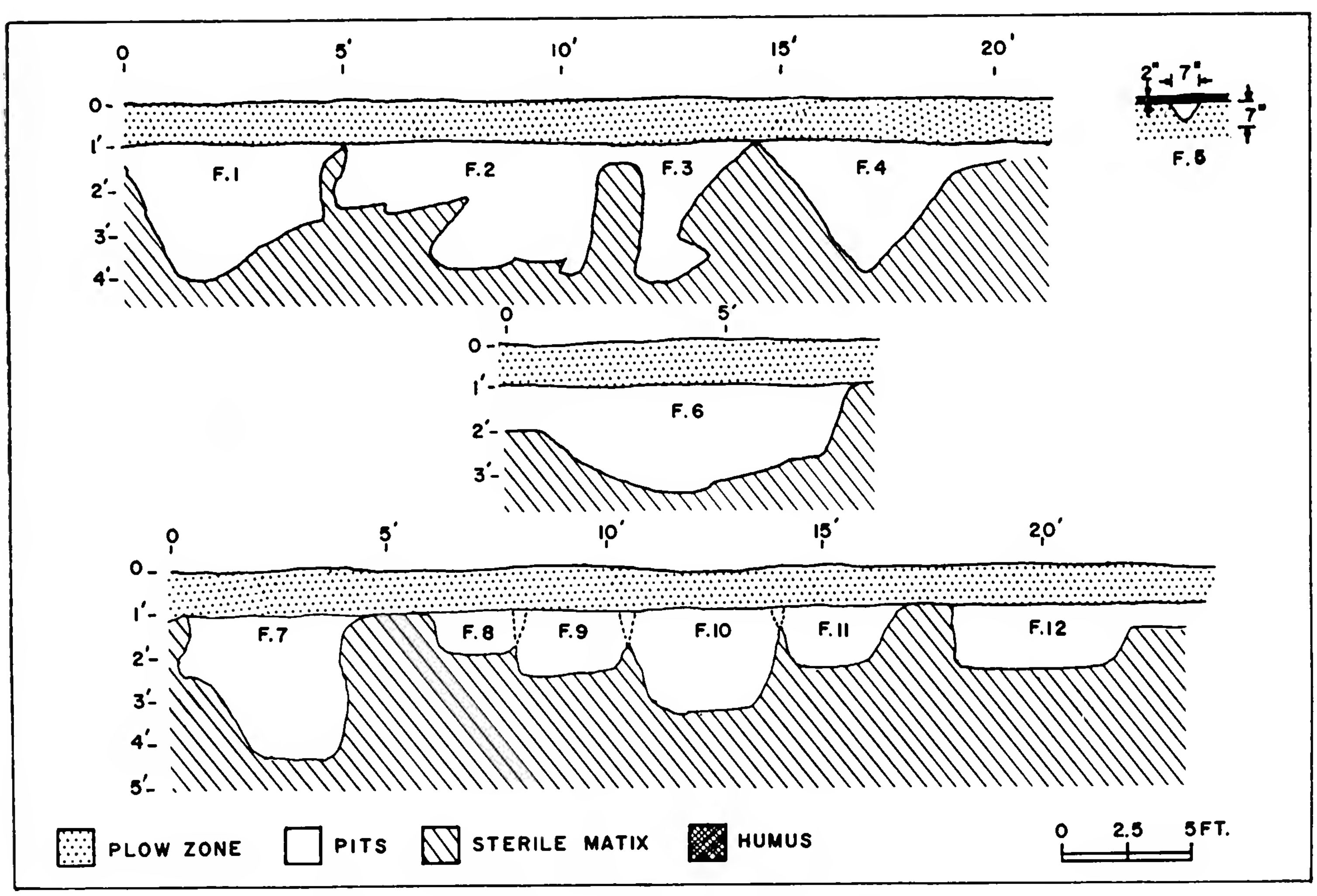

Fig. 2.—Profiles of pits at the Beake Site.

tures were uncovered horizontally. The features were large and in certain cases, namely 8, 9, 10 and 11, intruded into each other.

Analysis. The site has only two traits which can be used in deciding its cultural affinities, the pottery and the pits. The faunal materials were too scant to be of use. The identified lithic remains are not useful, because they were surface finds. The pottery consisted of two types, Late Woodland Lake Michigan Ware in pits 1, 3, 4, 7, 8 and 10, and Upper Mississippian Langford Plain in pits 1, 6 and 9.

Two alternate hypotheses can be suggested from the evidence found at this site; (1) the site was occupied by Late Woodland people who were in contact with Upper Mississippian people, or vice versa, or (2) the site was occupied by both groups of people, but at different times. The first hypothesis is based on the fact that the two types of pottery occur together in feature 1. The alternate hypothesis is based on the fact that some of the pits intrude into each other. This intrusion is best illustrated by features 8, 9 and 10, where the profile of the site shows the physical intrusion of pit 9 into pits 8 and 10. This intrusion is shown in the pottery distribution: Lake Michigan pottery in features 8 and 10, with Langford Plain in pit 9. Therefore, it seems to me that the evidence strongly indicates two occupations, an earlier Late Woodland one, which is later intruded into by one of Upper Mississippian peoples.

The Half Day Club Site

The Half Day Club Site (IAS No. L-2) is located south of State Highway 22 (Half Day Road) and west of the Des Plaines River, on the center of the east boundary of the Southeast 1/4 of the Southeast 1/4 of Section 15, Township 43 North, Range 11 East, about a half a mile east of Chicago's O'Hare Airport in Lake County (Figure 1).

The site was surveyed in 1919 by A. F. Scharf and recorded in the Chicago Historical Society 1919 Map #124, Volume 2; it was again surveyed in 1955 by the Illinois Archaeological Survey. In 1919 a village area and two mounds were reported. At that time the site was believed to cover an area of about 75 yards north and south and 50 yards east and west. One mound was 18 feet high by 50 in diameter and the other was 14 feet high by 40 feet in diameter. Unfortunately in 1952 the bulk of the site with the mounds was destroyed through gravel and sand pit operations. Thus, all the materials to be discussed here are those which could be salvaged when the destruction of the site came to the attention of the Illinois Archaeological Survey. The notes and artifacts for this part of the report were collected by Mr. Henry J. Rodemaker and Mr. James R. Getz to whom the author is most grateful.

That part of the site which was salvaged consisted of a burial and a group of eleven large pits which were located south of State Highway 22 on the south ridge of the site. Because the complete field notes and other information was not available (provenience is known for only one feature, number 10) this report will mainly be a description of the materials found.

Burial. The burial was that of a

female in her late twenties, who was about five feet two inches tall. The bones were fragmented and two of the fragments were charred. Apparently it was a bundle burial, inasmuch its orientation was not recognizable.

Artifacts. There were five artifacts of bone. One was a bone splinter awl 7.6 cm long and 0.9 cm wide. There were two incomplete bone beamers, 8.8 cm and 12.9 cm in length. Both were made of deer long bones. Two broken wheel-shaped pendants of gill bone, approximately 3.3 cm in diameter, were similar to those found at Plum Island (Fenner, 1963) and the Zimmerman Site (Brown, 1961).

Eighteen stone artifacts were found. Three were very thin and finely made small, triangular projectile points similar to those found in Upper and Middle Mississippian sites. Two of the points were broken, but the complete one was 2.0 cm long, 1.5 cm wide and 0.3 cm thick. All were of whitish chert. Another projectile point was a large broken corner-notched point of dark grey chert, broader than long, and similar to Hopewellian points (Mc.Gregor, 1958, p. 111-112). Another projectile point made of whitish chert, was 3.4 cm long, 1.7 cm wide and 0.7 cm thick. This point had convex sides, was corner-notched, and had a broken stem.

One rectangular based drill had a head 1.5 cm long and a total length of 4.25 cm; the base was 1.4 cm wide and the head or bit of the drill was 0.6 cm wide at the base junction. This drill was similar to those found at the Zimmerman Site. One flake knife, 2.2 cm long and 1.2 cm wide, was pressure flaked on one edge only.

Besides two random flake scrapers and four bi-convex core scrapers, there was one rectangular shaped flake scraper worked on all four sides, 2.8 cm long, 1.9 cm wide and 0.5 cm thick, and one rectangular shaped side scraper, triangular in cross-section, 3.5 cm long, 2.6 cm wide and 1.3 cm thick. A micro-scraper or punch, worked on one edge and almond-shaped was 2.3 cm long, 0.9 cm wide and 0.6 cm thick. Some of the scrapers were similar to

TABLE 1.—Percentages of Occurrences, Location, and Classification of Ceramic Materials From the Half Day Club Site.

Type	Totals	Percentages	Feature 10	Questionable
Madison Cord-impressed	1	.3	1	..
Madison Plain	5	1.5	..	5
Lake Michigan Ware	67	20.1	67	..
Fisher Cordmarked	1	.3	..	..
Langford Cordmarked red slip	1	.3	..	..
Langford Trailed	1	.3	..	..
Langford Cordmarked	135	40.6	16	15
Langford Plain	113	35.1	3	20
Miniature	1	.3	..	1
Miscellaneous	4	1.2	..	4
Totals	329	100.0	87	45

those found at the Zimmerman Site, but the last two were unique.

Two stone pendants of ovoid shape, 3.1 and 2.0 cm long, 3.1 and 2.3 cm wide and 1.4 and 1.5 cm thick were found, which were similar to those found at the Zimmerman Site. The remainder of the stone material consisted of 102 unworked chert chips and nine pieces of rough rock.

Ceramics. A list of the pottery found at the site is presented in Table 1. The sherds listed as questionable are those obtained from the family of the man who originally dug them. It is the family's opinion that they came from one of the mounds before it was removed by gravel operations.

Approximately 98.5% of the sherds could be classified into existing types. Only four miscellaneous sherds occurred, one grit-tempered and three granite-tempered, and all were grey in color. The Fisher and Langford types (Griffin, 1946, p. 13-21) are Upper Mississippian and constitute 76.6% of the total. The Madison and Lake Michigan sherds are Late Woodland (Wittry, 1959, p. 200-203 and Bennett, 1945, p. 80-81) and constitute 21.9% of the total.

TABLE 2.—Total Numbers, and Percentage of Occurrences of Fragments of the Kinds of Animals Found in the Half Day Club Site.

	Number of Fragments	Percentage Identified	Percentage of Ident. to Unident.	Percentage of Total
Mammals				
Deer	74	97.3	18.6	
Raccoon	2	2.7	.5	49.4
Unidentified	322	....	80.9	
Fish				
Bass	5	38.6	1.3	
Drum	4	30.8	1.0	
Catfish	2	15.4	.6	
Gar	1	7.6	.3	36.9
Buffalo fish	1	7.6	.3	
Unidentified	285	....	96.5	
Bird				
Turkey	1	100.0	2.0	
Unidentified	47	.....	98.0	6.0
Shell				
Straphitis rugosus	2	50.0	3.8	
Amblema rariplucata	1	25.0	1.9	
Amblema costata	1	25.0	1.9	6.5
Unidentified	49	....	92.4	
Snail				
Stagnicola exilista	1	50.0	25.0	
Pleurocera acuta	1	50.0	25.0	.4
Unidentified	2	....	50.0	
Turtle (*Pseudemys scripta*)	7	100.0	100.0	.8
TOTALS	808	12.7	87.3	100.0

Faunal Remains. Table 2 is a list of the faunal remains from the site which were identified by Harald P. Jensen, Jr. a student at the University of Illinois.

Judging from the types of faunal remains present and the fact that there was no evidence of agriculture, it would seem that the economy of the people was basically one of hunting and fishing.

Analysis. The pottery from the site consisted of two types, Late Woodland 21.9% and Upper Mississippian 76.6% both of which were found in feature 10 and the mound. The lithic materials consisted of Mississippian projectile points, a Hopewellian point which was probably intrusive, and some points of unknown cultural affiliation. The drill and bi-convex scrapers have affinities to both Late Woodland and Upper Mississippian cultures. There were also some unique lithic materials. The bone remains have affinities to both cultural groups mentioned above, except the gill wheel pendants which have Upper Mississippian affinities. The economy which is suggested from the archaeological evidence would be indicative of Late Woodland culture, but it would also be possible for it to be a seasonal Upper Mississippian hunting and fishing camp. Because of the lack of detailed information, traits like the mounds and pits could be classified in both Late Woodland and Upper Mississippian cultures.

There are two hypotheses which can be inferred from the evidence; (1) the site was occupied by Late Woodland and Upper Mississippian peoples, but at different times, or (2) the site was occupied by Upper Mississippian peoples who were in contact with Late Woodland peoples. It seems to me that the idea of separate occupations is unlikely, because the pottery of both cultural groups was found together in relatively large quantities, which would rule out accidental intrusion. The presence of Late Woodland pottery indicates that the two groups had some type of contact with each other, probably through trade. The site was probably a seasonal Upper Mississippian hunting and fishing camp, since we have no good evidence of the practice of agriculture at this site. Although it is possible that the evidence of agriculture and permanent settlement was lost through the removal of the bulk of the site by the quarry operations.

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Manuscript received March 25, 1963.

ON A NEW PROOF OF THE INFINITUDE OF THE PRIMES

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ABSTRACT. — A certain (multiplicative) number-theoretic function, Ψ, associated in a natural way with a new model of the Fundamental Theorem of Arithmetic is sufficiently well endowed with *invariance* characteristics so as to provide the basis for another analytic proof of Euclid's Theorem.

The purpose of this note is to relate a theorem which dates from antiquity (Euclid of Alexandria, *c.* 300 B.C.) with the author's recent reformulation of the *Unique Factorization Theorem* of elementary number theory (Mullin, 1963a, 1963b). The proof is nonelementary in that it uses ideas from analysis; specifically it uses the existence of the limiting density of fixed-points for a certain (multiplicative) number-theoretic function, Ψ, to be defined later. Furthermore the proof is distinct from the analytic proofs given by Vinogradov (Vinogradov, 1954, p. 151-152). However, it is not *necessary* to use the Ψ-function to prove Euclid's theorem any more than it is necessary to use Riemann's zeta-function. The claim to novelty for this note is that the number-theoretic function, Ψ, rich in properties and occurring quite naturally in the context of a *new* model of the Fundamental Theorem of Arithmetic provides such natural structure (specifically that associated with the useful algebraic notion of *invariance*) as to permit a proof of Euclid's Theorem.

As a point of entry, consider Gauss' model of the *Fundamental Theorem* (Gauss, 1801), *viz.*, every natural number n has a *unique* representation in the form $n = p_1 \alpha_1 . \ldots . p_m \alpha_m$, where the p_i are *distinct* primes. Suppose, for natural number n, one applies Gauss' model to its own natural number exponents and to their exponents etc. (i.e., use induction) until the process terminates by the Well-ordering Principle. Call the final *unique* configuration of primes alone a *mosaic*; for example, the mosaic of 400 is $2^{2^2} \cdot 5^2$. Now define the (multiplicative) number-theoretic function Ψ as follows: $\Psi(n)$ is the simple *product* of the primes alone in the mosaic of n. E.g., $\Psi(400) = 80$.

Lemma. Let n be a natural number > 1. Then $\Psi(n) = n$ if, and alone in the mosaic of n. E.g., Ψ $(400) = 80$.

Proof. First note that $\Psi(n) \leq n$ for every natural number n. Clearly any square-free number is invariant under Ψ. Twice an *even* square-free is invariant under Ψ since $\Psi(4) = 4$ and every (odd) square-free number is invariant. No other natural number is invariant since one is changing an exponent into a multiplicative factor which strictly decreases the number.

Theorem. There exist infinitely many primes.

Proof. Suppose there are only finitely many primes. Then, by the *Fundamental Theorem* (whose proof is independent of the infinitude of the primes) there would be only finitely many square-free numbers. Hence, by the Lemma, only finitely many natural numbers would be invariant under Ψ. Let α be the distribution function of the fixed-points for Ψ. Hence, with $n \to \infty$, $\lim \alpha(n)/n = 0$. But, with $n \to \infty$, $\lim \alpha(n)/n = \lim (Q(n)/n + (1/2)(1/3)Q(n)/n) = 6/\pi^2 + 1/\pi^2 = 7/\pi^2$, where Q is the distribution of the square-free numbers. The latter result follows from Euler's Identity whose proof is independent of the infinitude of the primes. Hence, by *reductio ad absurdum*, there are infinitely many primes.

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Manuscript received October 21, 1963.

NEWS AND COMMENTS

Now we have "News and Comments." The word "Notes" will head a new section in future issues of the Transactions. Breath-taking changes such as these are expressions of faith in the continued growth of our publication and signs of a desire to have a more adaptable media of publication for the benefit of the members of the Academy. A few moments of enthusiastic discussion at the Third Council Meeting, held at Illinois Wesleyan University, yielded the idea that caused these changes and we hope the idea is received equally enthusiastically by the members of the Academy.

Starting with the September issue the Transactions will have the new section headed "Notes" as a place for reports, notes, and similar articles. These articles will be in eight-point type, one following the other on a page, and may vary in length according to the desires of the author. The principal joy in this idea is that the author will have the minimum wait in time for publication. The Council recommended that every effort should be devoted to getting these papers into the "next issue that goes to press."

There are some problems of format to be resolved, but do not let this deter any member from sending in manuscripts for the new section.

The remark about a "minimum wait in time for publication" of notes deserves amplification. Copy for the issues are submitted to the State Printer as early as possible in the months of February, May, August and November. Allow all the time possible for review and editing. Five months is probably the minimum time possible under these arrangements. Where else can you get such a bargain for a five dollar membership?

JUNIOR ACADEMY

FILM REVIEWS

MILTON D. THOMPSON, *Chairman*
Educational Films Evaluation Committee, Illinois State Academy of Science

FILMS

1. COPPER MINING (Pat Dowling Pictures), 16 mm.
   14 min., color, j-h
   Reviewers: Richard Leary and Herman Eifert

This film begins in an open pit mine and, step by step, shows the mining, transportation of ore, the purification processes ending with 99% pure blister copper. The sequences are very smooth; the color is excellent. An individual watching this film can almost feel the intense heat, the physical exertion, and personal problems of copper mining. Explanations are clarified in several instances by diagrams.

2. INSECT ENEMIES AND THEIR CONTROL (Coronet), 16 mm.
   11 min., sound, black and white, $50; color, $100. j-h
   Reviewer: James M. Sanders

This film deals with insects that attack field crops, affect health or produce property damage. The introduction presents a few useful insects and several destructive insects such as: grasshoppers, flies, termites, corn borer and codling moths.

Among controls suggested were resistant varieties, crop timing, and insecticides—both dust and spray. Biological controls cited included birds; parasitic wasps; insects, such as lady bird beetles predatory on insects or insect larvae; wrapping garbage in paper and tight garbage container covers; screen against flies and mosquitoes; chemicals which liberate gas, such as paradichlorobenzene and dry cleaning for clothes moths; and destruction of infested plants such as burning elm trees dead of Dutch elm fungus to destroy European bark beetles.

Photography was good. Some sequences, such as that of the Cotton Boll Weevil, were beautiful. Commentary voice was excellent, understandable, and the vocabulary simple.

Omissions in biological control were: failure to mention use of contagious diseases of insects, use of mating of prospective parents sterilized by radiation, and use of sex attractants for confusion and dispersion of mating males from females or to entice insects into traps.

FILM STRIPS

1. WHAT'S HAPPENING TO OUR NATURAL RESOURCES (*New York Times*, Times Square, New York, N.Y.) 56 frames, black and white, j-h.
   Reviewer: James M. Sanders

An excellent introduction to specific problems of conservation for anyone unacquainted with the entire field. It presents a general statement of dependence upon natural resources using the United States as an example. Both renewable and non-renewable resources, exclusive of man, are considered. Facts are succinct, interesting and modern in content. Significant attention is paid to national and international factors. An accompanying illustrated discussion manual clarifies and restates each general area very well.

The serious depletion of our high grade iron ore and our importation of ore and finished steel was not presented. The fact that our national cost of living index is the highest in history and still rising was not mentioned in the optimistic references to high standards of living. The fact that the "West" has 1/5 as much water but uses four times as much as the "East" (mostly for irrigation) was pointed out. The use of land in urban growth and expansion was presented as a necessary development. The present reviewer cannot agree.

That flow of food abroad has contributed to international good will toward the U. S. is not supported except by a bare statement.

2. EXPLORING THE WORLD OF NATURE, (Society for Visual Education, Inc., 1345 Diversey Parkway, Chicago, Ill.), Six filmstrips of 47-51 frames each. Color, $6; set, $32.40 j-j.
Reviewer: James M. Sanders

These strips review, briefly and accurately, the ecology of selected environments with significant details of the limited local situations described. Interactions of plants and animals in specific areas and seasons are shown and simple equipment which might be of aid to the study. Color photography is excellent, supplemented by a few diagrammatic drawings also in color. Each talk begins with a list "This film strip will help you discover," and there are some questions as the frames progress with "follow-up activities" at the close and "questions for review."

A423-1 LET'S EXPLORE A FIELD

A423-2 LET'S EXPLORE A GARDEN

A423-3 LET'S EXPLORE A LAWN

A423-4 LET'S EXPLORE A POND

A423-5 LET'S EXPLORE A STREAM

A423-6 LET'S EXPLORE A WOODLAND

No. 3 is potentially useful to anyone who is a beginner in lawn care. No. 4 explains the progress of a lake as it fills with vegetation and slowly develops toward becoming land. No. 5 gives simple formulae for calculating stream volume flow in gallons per second which would be of use to anyone interested in quantitative water movement. Problems of pollution and how detergent foam can be a pollution indicator are also shown; references to fish habits and food scavengers and predators show simple food chains. No. 6 emphasizes importance of forest litter, differences between parasitic and saprophytic fungal habits, significance of birds and organisms living in or under logs and stumps.

There were a few lapses in Strip No. 1, "Bacteria capture nitrogen in swellings on the clover roots;" and in No. 4, beavers are shown as animals which "live below the ice." Except for their flattened tails, they could have been muskrats; maybe they were. Advertising frames at the close of some of the strips list other titles which have no direct relation to the films just shown and contribute nothing to their value for the children at whom the material is directed.

This reviewer highly commends these films.

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 and one carbon copy should be submitted.

Titles should be brief and informative. The address or institutional connection of the author appears just below the author's name. An abstract must accompany each article. Subtitles or center headings should be used; ordinarily one uses subtitles such as *Materials, Methods, Results, Discussion, Summary, Acknowledgments,* and *Literature Cited.*

No footnotes are to be used in the text.

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. McGraw-Hill Book Co., New York. 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 and manuscripts are returned to the Editor.

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Land of Lincoln

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OTTO KERNER, *Governor*

SEPTEMBER 15, 1964

CONTENTS

PRESIDENTIAL ADDRESS

WHAT INSTRUMENT DO YOU PLAY?

ELNORE STOLDT
Jacksonville High School, Jacksonville

It might be that there is such an animal as a typical scientist. Be that as it may, there seems to be evidence that, along with their other traits, scientists tend to an interest in music. Scratch any scientist and you are apt to permit the escape of quarter and half notes instead of red and white corpuscles. It might be argued that a similar tendency occurs in other professional groups, but among scientists it is particularly striking. It seems appropriate to allow curiosity to delve into reasons for the situation.

There appears to be no thoroughgoing analytical study to read about, but would it not be rather difficult to determine the exact extent to which a person is a good scientist, or to tell how deep goes his love of music? This study sorts out some facts and comments and proves not a thing.

The point is made here that scientists as a group have an *interest* in music and a liking for it. They are not necessarily talented, either as composers or as performers, although talent is often present to the extent that the scientist becomes known also as a musician. Pearl Buck, in her novel "Command the Morning", affirms that there is something of the artist in every scientist (Buck, 1959).

It has been interesting during the past four or five years to notice what scientists mention as hobbies, a listing of which will more often than not include a music activity. You know about Einstein and his violin. Borodin, who became one of the "mighty five", gave up a career in chemistry and medicine for music, and Schweitzer could have done so but chose otherwise. Occasionally, a musician and a scientist, each attracted by the qualities or abilities of the other, become closely-attached friends, a case in point being the friendship of Brahms and the Austrian surgeon Billroth, himself a brilliant musician.

In the first place, assuming that the particular association to which we direct attention is a sort of symbiosis and the scientist one of the symbionts, then what could the music as the other symbiont do for him?

Obviously, there can be no argument against the idea that whatever is pleasing can provide release at eventide of the tensions that have built up all day in a crowded laboratory, an over-silent workroom, or a mosquito - populated swamp. The ''music hath charms to soothe'' concept may, however, be dismissed as inapplicable, for the savage scientists form only a minority group. But music is *more* than a sedative.

Every scientist, whether aware of it or not, seeks to express what he learns, and music gives him a different way of saying something, so that he is not limited to the words of a language. Strangely, an idea turned loose to float on sounds, sounds arranged by the scientist or merely brought to his consciousness from a a composition by someone else, may later be caught and congealed into language printed on a page, and thereby left for all the world to use.

But there is also the possibility that music, in whatever form it appeals to him, could be a stronghold from which to fight the vast uncertainty of the times in which we find ourselves, uncertainty they say the scientists have brought upon all of us by providing tools and materials for human destruction.

In effect, it can be said that music offers to the scientist nothing more nor less than what it holds out to anyone else; nevertheless, the point remains: scientists are apt to seek something in music.

Now the scientist, the other symbiont, should have something to do for music.

In spite of a study made by Margaret Mead a few years ago, many persons still picture a scientist as a partly - bald, stooped, nearsighted man with a butterfly net in one hand and a magnifying lens in the other. This man is considered to have almost as much warmth as a computer, while a woman is not even imagined as a scientist. Certainly, such a caricature that has no factual basis should be erased. In casual conversation at the dinner of the Academy Conference in 1962, Dr. Paul M. Gross, then President of the A. A. A. S., kept repeating that we must encourage students toward graduate work in science and must destroy the popular image of scientists as unconventional, non-conforming people, and a large number of his fellowscientists subscribe to Dr. Gross' opinion. That leaves scientists with the responsibility of contributing to the arts as well as to the sciences. Assuming, then, that a scientist, male or female, is a standard-model human being with training in a special field and with a normal amount of sensitivity, what could he contribute to music?

Music needs to be supported by a willingness and ability to invent. Inventiveness, the scientist, by training or innate tendency, understands. Obviously, if no one had ever been interested in mechanics and designs, the only instrument available would be the human voice, untrained and without chance of improvement. Unless someone tried new combinations and sequences of tones, there would be few songs to sing.

There are those who argue that scientists have recently been carrying inventiveness too far. Digital computer numbers converted to sound waves, converted to tones,—but converted to *music?* Though it might have programmed itself into the clumsy hands of the sorcerer's apprentice, the computer must be claimed by the inventing scientists. The work done rather recently by the Bell Telephone Laboratories and other research groups could open up unlimited instrumental possibilities, while also leading to clearer and more pleasant vocal communication. For one thing, a live musician never can duplicate exactly his performance of a composition. While this provides interesting and challenging variety, it leaves no exact record. It could be valuable to a student of music to know how a composer played his own work. A computer can provide exact repetitions, as well as predetermined variations, that would probably be more valuable for study and analytical purposes than for enjoyment. It has already been shown that it is possible for the computer to produce a very great variety of sound combinations. It can compose. What it composes is not very well liked by many persons, but many of us are not overly-attracted to jazz compositions, and some of us find Bach dull. Whether or not the creative musicians ever make extensive use of the computer as a tool, the scientists have given them the invention and ideas for its use. If the computer comes to be widely used for performance of music, one wonders what might become of some of the string quartets, choruses and other performing groups that scientists organize among themselves. Quite probably, a computer, concert grand or table model, will take its place as one more tool and will not exclude the others. What instrument will you play then?

Trained to patience and perseverance, the scientist could bring persistence to both composition and performance of music. The materials in the fields of both science and music are too extensive to comprehend without long, hard, intense work.

The scientist's sense of orderliness and design might be another contribution. After Pythagorus pointed out the relationship between the length of a string or a column of air that is vibrating and the pitch of the sound so produced, other Greek scientists worked with sound, allowing the science of acoustics to develop. From the investigations of Helmholtz there came the possibility of harmonics, so that a musical composition did not have to remain confined to an unaccompanied melody. While a large number of physicists continue to study sound, all present-day scientists who enjoy music are inclined to enjoy it to a greater extent because of their ability to comprehend its patterns or to devise new patterns if they are scientist-composers.

Those of us who teach in high schools are familiar with the remarks of students indicating that they simply cannot study unless radio or television is turned on; many of us would like very much to know if students would not learn more science in an environment providing less auditory stimulation, but the chances of our finding out about this are slight. In any case, the students never seem to know what music they have heard, so they really do not know the music, either. A trained scientist is apt, rather, to be attentive to music he hears, performs, or composes, even critical of it; accordingly, because he has understanding of the music, his enjoyment becomes greater. Then he will buy records, attend performances, support civic symphonies and perform great compositions for his own pleasure, all of which tends to increase the public demand for the so-called ''good'' music — the kind persons want to hear in many repetitions.

There is no way of telling how much music we have lost, although possibly it is still all floating in the atmosphere and will sometime be recovered either exactly as it was or with time-worn edges. Fortunate it would be if at least some of the methods now available for preserving materials had been developed earlier in order to give us unfaded scores on paper that would never crumble and to make it possible to refer repeatedly to original manuscripts instead of to copies of copies. We know something of the forms of the early Greek music but nothing of its sound, for the invention of the phonograph came too late and in its early days was not able to reproduce a performance convincingly.

It is not difficult to indicate how music can be of value to a scientist, and how scientists can influence development and use of music, but to seek the reason for the actual symbiotic relationship (the interest of the scientist in music) it is pertinent to look at possible factors that might be present in both the scientist and the musician, especially the composer.

For one thing, indicating to scientist or musician that he cannot or should not do a thing is to challenge him to prove you wrong. Do you remember that Robert Schumann slipped a recognizable bit of the ''Marseillaise'' into the first movement of the ''Carnival Jest from Vienna'', and that at a time when the ''Marseillaise'' was not at all popular? Suppose we stated that it is impossible to grow persimmons on pine trees. Almost surely at the next annual meeting of the Illinois State Academy there would be a paper presented in the botany section, complete with slides illustrating persimmons on a pine tree.

Igor Stravinsky (Stravinsky and Craft, 1962) thinks that the muscian ''should be wary of science, which is always neutral''; that is to say, neither positive nor negative in its approach. Scientists probably do not think of themselves as making neutral approaches to problems; ''unbiased'' is a better word for their attitude. They would agree with Stravinsky that music and mathematics are never purely logical, for if those disciplines were limited by logic there would be few new ideas presented.

At one time Bertrand Russell expressed the opinion that science and music each searches for the truth. Although to understand this we have the problem of defining truth, an evasive term, it does seem that each scientist or musician is attempting to reveal that which is true to him. Do you think both would subscribe to Robert Frost's definition—''Nothing is true except as a man or men adhere to it, to live for it, to spend themselves for it, to die for it'' (Untermeyer, 1963)?

In an article appearing in *Saturday Review* in February of this year James Baldwin says ''the primary distinction of the artist is that he must actively cultivate—the state of being alone''; then, later, ''The artist is distinguished from all other responsible actors in society — the politicians, legislators, educators and scientists by the fact that he is his own test tube, his own laboratory'' (Baldwin, 1964). Is the scientist really so different in this respect? Surrounded by all the physical equipment of the laboratory, are not his achievements still produced within the test tube of his own mind?

Virtually all the ideas here presented have been discussed at different times and by persons of varying backgrounds, compounding examples of scientists interested in music and emphasizing the imaginative qualities of scientific and musical persons, but there seems still to be nothing very specific by way of explanation. There are several enlightening articles in an issue of *The London Times Literary Supplement.* The one written by P. B. Medawar (1963) is thorough about analyzing the imaginative way in which a scientist works. The featured article by C. P. Snow bears the title ''The Two Cultures: a Second Look'' and is, of course, a reappraisal of his original discussion-provoking lecture emphasizing science as one culture and literature, not music, as the other, so that what he says does not apply to the present discussion except to the extent that literature and music have some similarities. He says that in the United States, as compared with European countries, the division between the two cultures ''is nothing like so unbridgeable'' and that in several of our larger universities ''students of the sciences are receiving a more humane education'' (Snow, 1963). If this is the general situation, then perhaps the connection between scientific ability and music interest is more noticeable in the United States than it would be in some other parts of the world.

We have, in these remarks, indicated a few fragments of themes that make up the whole symphony in which the scientist, the musician, the science, and the music are exposed, developed, harmonized, merged finally into one resounding chord. Each scientist is assigned a chair for a performance that lasts as long as his life, and he may choose his own instrument. He is obliged only to play his very best and to leave each phrase a little better than he found it. ''Real happiness'', said Schnabel, ''will only be established in human beings when much will be expected from their inner qualities and higher potentialities'' (Schnabel, 1963). In the grand performance that molds together all the productiveness, all the happiness of human lives, what instrument do *you* play?

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RAT DIAPHRAGM CARBOHYDRATE METABOLISM IN THE PRESENCE OF THIOLS

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ABSTRACT. — The influence of equivalent concentrations of thioglycolate, β-mercaptoethanesulfonate, α,α′-dimercaptoadipate, cysteine and dithiodiglycolate on carbohydrate metabolism of the rat diaphragm was ascertained. Because of the divergent effects noted with the sulfur compounds tested, the over-all configuration, rather than the sulfhydryl group as such, constitutes a most important factor affecting carbohydrate metabolism.

The rat diaphragm has been used extensively in *in vitro* metabolic studies of the influence of hormones, drugs and metabolites on muscle. Knowledge is lacking on the correlation of resting muscle metabolism with that of the functioning tissue and various facets of this problem have been reviewed by Szent-Györgyi (1951). The rat diaphragm was first employed by Takane (1926) in relation to the *in vivo* effects of insulin on carbohydrate metabolism and later studied in greater detail by Gemmill (1940). It is particularly suitable for immediate use without extensive manipulations because of its inherent structure. The thickness of the diaphragm meets the qualifications necessary for the rapid exchange of gases to and from the cells and can be determined from the surface area and specific gravity (Villee et al., 1949; Umbreit et al., 1951). The *in vitro* results with rat diaphragm might correlate closely with those observed in the *in vivo* response because the number of intact cells remains high and the structural characteristics, such as the vital membrane between the medium and the intracellular fluid, undergo little alteration.

The study of Stadie and Zapp (1947) on the influence of various media on glucose utilization by diaphragm as such and in the presence of insulin is classical. In the pH range of 6.3-7.6, the effect of insulin was constant. With untreated diaphragm, oxygen was utilized at a steady rate for a period of six hours and glycogen synthesis was maximal after about one hour. On introduction of insulin, although the oxygen consumption remained constant, increased glycogen synthesis continued for approximately two hours. The ionic concentration of the medium likewise affects the extent of glycogen formation; magnesium and phosphate ions at high levels depressed glycogenesis in the presence or absence of insulin and glycogen values were lower on deletion of the cation. Glycogen synthesis is affected by diet, sex, insulin and time of fasting, fed rats with an initially high glycogen content displaying the greatest amount of glycogenesis (Kerly and Ottaway, 1954). The metabolic fate of glucose as well as acetate and pyruvate utilized by this muscle has been elucidated (Villee and Hastings, 1949a,b; Walaas and Walaas, 1950; Foster and Villee, 1954). On the basis of experiments in which diaphragm was incubated in the absence of glucose, metabolites other than glycogen were thought to comprise the main source of energy (Haugaard et al., 1951).

Of the various agents investigated in relation to carbohydrate metabolism by the rat diaphragm, insulin is unique in producing an increase in both glucose utilization and glycogen deposition. A direct combination occurs between insulin and the muscle (Stadie et al., 1949a,b). The effect of pituitary hormones, sterols and epinephrine and other amines on diaphragm metabolism has been reported (Verzár and Wenner, 1948; Li et al., 1949; Stadie et al., 1951; Ellis, 1952).

In a previous study (Spencer et al., 1964), the oxygen uptake by rat tissue slices was ascertained in the presence of varying concentrations of the important thiol, thioglycolic acid (TG) and under more limited conditions, with β-mercaptoethanesulfonic acid (MES). As such data reflect over-all tissue response, it was thought that more specific effects attributable to TG might be observed by a study of muscle carbohydrate metabolism. Accordingly, TG and several related thiols were compared by this approach. The additional compounds, included in order to deduce whether the changes, if any, engendered by TG were specific for this molecule alone or would extend to other thiols, comprised MES, cysteine and α,α'-dimercaptoadipic acid (DMA). Dithiodiglycolic acid (DTDG), though a disulfide, was also investigated as it represents the readily obtainable oxidation product from TG. A statistical analysis was carried out on the changes observed in glycogen content, glucose utilization and oxygen uptake by the respective rat hemidiaphragms.

Experimental Procedure

Commercial TG from Evans Chemetics Company was distilled twice under vacuum (b.p. 105-108° C at 20 mm; collected in water). The corresponding disulfide, after two recrystallizations from water, melted at 107-108° C. L-cysteine originated from Nutritional Biochemicals Corporation and MES and DMA which were prepared by the Toni Company, were of high purity. The acids, except for L-cysteine, were introduced into water and the pH adjusted to 7.2 with aqueous sodium hydroxide. The stock solutions contained 200-300 mg per ml as based on the free acid. The medium for the incubation of disphragms comprised the one described by Stadie and Zapp (1947): 0.04 M Na_2HPO_4, 0.005 M $MgCl_2.5H_20$ and 0.08 M NaCl; pH 6.8-7.0. Glucose was used in this mixture at a level of 110 mg %.

Male rats averaging 150 gm in weight at the time of experimentation were of a Wistar and Sprague-Dawley cross. They were starved for 24 hr in order to deplete glycogen and killed by decapitation. The hemidiaphragms were removed quickly with minimum trauma and bleeding, care being exercised to avoid cutting the inferior vena cava and immediately placed in individual tubes, each containing 2.0 ml of ice-chilled medium. The trimmed hemidiaphragms were blotted, weighed, placed in the individual vessels containing 1.5 ml test medium and incubated for 90 min under 100% oxygen at 37.5°C. The appropriate solutions without tissue were simultaneously incubated. In the first series of experiments, beakers of 20 ml capacity containing the individual hemidiaphragms with the respective media were incubated in a metabolic shaker (Dubnoff, 1948). The chamber was flushed with 100% oxygen for a 10 min period at a gas flow of 5 cu ft per hr. During incubation, the gas flow was reduced to one cu ft per hr. In the later studies, a similar procedure was carried out in the Warburg apparatus equipped with 18 flasks except that the oxygen uptake was also ascertained.

Dreywood's anthrone reagent was used for the determination of both glucose and glycogen (Morris, 1948). After removal of the hemidiaphragms at the conclusion of the experiment, an aliquot of the mixture was diluted 1:50 with water and the glucose analyzed directly. The hemidiaphragms were rinsed twice with phosphate-saline medium, being blotted before and after each washing to remove adherent solution. They were then immediately placed into tubes containing 0.3 ml of 30% potassium hydroxide and digested for 30 min in a boiling water bath. Glycogen was precipitated in the presence of 0.1 ml of 2% sodium sulfate on addition of 1.2 ml of 90% ethyl alcohol by the procedure of Good, Kramer and Somogyi (1933) as modified by Walaas and Walaas (1950).

In the statistical analysis of data, as the Warburg apparatus imposed a limitation on the number of tissues incubated simultaneously, the balanced incomplete block design as outlined in Figure 1 was applied (Cochran and Cox, 1955).

Results

Metabolic Shaker Series. A total of 50 rats was equally divided between the five compounds at each of the following concentrations. Ten animals were used per day (replication), alloting two rats to each treatment.

In the first experiment, the effect of the thiols at a level of 5 x 10^{-5} N was ascertained. The two pairs of hemidiaphragms under the same

	Block	Replication I				....	Replication VII			
Treatments (1-8)	(1)	3	5	1	4	(13)	1	4	5	8
	(2)	7	8	2	6	(14)	2	3	6	7

Figure 1.—Diagram showing the incomplete block design employed for the incubation study of hemidiaphragms in the Warburg apparatus. In text and tables, the parts of this design are referred to by the following symbols: R = 7, the number of replications or days; B = 14, the number of blocks or Warburg runs; T = 8, the number of treatments, each being the difference in glucose utilization, total glycogen content, or oxygen uptake between the control and the treated hemidiaphragm of each pair; k = 4, the number of treatments within each block; n = 7, the number of paired hemidiaphragms used for each treatment.

TABLE 1.—Summary of the Average Effects Produced by the Sulfur Compounds on Rat Hemidiaphragms (metabolic shaker series)[a,b]

Treatment	Concentration	Change in glucose uptake[c]	t	Change in glycogen content	t
	N	μg/mg wet tissue/hr		μg/mg wet tissue/90 min	
TG	5×10^{-5}	0.73 ± 0.311	2.35*	0.15 ± 0.059	2.54*
	5×10^{-3}	0.96 ± 0.399	2.41*	0.74 ± 0.252	2.94**
MES	5×10^{-5}	-0.02 ± 0.199	0.10	0.27 ± 0.096	2.81*
	5×10^{-3}	0.63 ± 0.354	1.78	-0.25 ± 0.117	2.14
Cysteine	5×10^{-5}	-0.04 ± 0.346	0.12	-0.19 ± 0.151	1.26
	5×10^{-3}	0.22 ± 0.263	0.84	0.16 ± 0.256	0.62
DTDG	5×10^{-5}	0.09 ± 0.433	0.21	0.23 ± 0.096	2.40
	5×10^{-3}	0.25 ± 0.231	1.08	0.17 ± 0.209	0.81
DMA	5×10^{-5}	0.59 ± 0.346	1.70	-0.23 ± 0.111	1.63
	5×10^{-3}	-0.10 ± 0.137	0.73	0.19 ± 0.240	0.79

[a] The means ($\pm$ s.e.) are deduced for 10 paired hemidiaphragms.
[b] A positive mean difference indicates a decreased response in the presence of the sulfur compound.
[c] The amount of glucose utilized was based on the final concentration of the respective media incubated without tissue.
* Significant at the 5% level of probability.
** Significant at the 2% level of probability.

treatment within replication were assigned to the media in such a way that if the left hemidiaphragm of one pair were incubated in the control solution and the right in the test medium, the order would then be reversed for the second pair. In this manner, the same number of 'right' and 'left' hemidiaphragms were subjected to treatment and no significant difference was apparent with either tissue. A difference in effect between test compounds on glycogen content is indicated (Table 1). The treatments, MES and DTDG, caused an apparent decrease in the amount of glycogen, while the reverse was observed for DMA and cysteine.

In the second experiment, each of the paired hemidiaphragms was allotted in a random order directly to beakers containing chilled media with or without glucose during the pre-incubation period, the thiols being tested at a level of 5 x 10^{-3} N. Replications again were found to have a decisive influence upon glucose utilization.

Although no difference in treatment effects was shown from the analysis of variance on glucose uptake, when the average differences for TG at 5 x 10^{-5} N and 5 x 10^{-3} N are compared to the mean difference of zero for a pair of hemidiaphragms treated alike, t values significant at the 5% level of probability result. This depression of glucose uptake reflects that of the corresponding final glycogen content.

Warburg Series. For the further study of the contrasting effects between TG, MES and cysteine, the Warburg apparatus was employed, allowing for the determination of oxygen uptake in addition to the glucose and glycogen analyses. Each of the thiols was tested at 5 x 10^{-3} N and 5 x 10^{-5} N. As indicated, two Warburg runs were required for each replication due to the limited capacity of the apparatus. Two treatments designated as Controls *1* and *2* were included, both consisting of the differences found between pairs of hemidiaphragms incubated only in glucose-containing medium. One side of each control diaphragm was termed the 'untreated', prior to incubation. The hemidiaphragms of each pair were assigned at random to the respective media (Figure 1). A total of 56 rats was equally divided among the eight treatments. No increase in precision for the evaluation of glucose uptake resulted under these experimental conditions, replications alone being highly variable in agreement with the previous results. In regard to the glycogen content, differences among treatments were substantiated in the analysis of variance (Tables 2 and 3). Unlike glucose and glycogen, analysis of the oxygen uptake data shows neither an influence of replications nor a diversification in treatment response. A marked decrease is noted with TG at 5 x 10^{-3} N corresponding to the glycogen depression (t test; Table 2).

Discussion

In the present series employing a metabolic shaker, TG and related sulfur compounds were compared at two separate concentrations, 5 x 10^{-5} N and 5 x 10^{-3} N, as to their effect on the isolated rat diaphragm. Ten animals were selected for each daily run, thereby allowing for a duplicate comparison of the five

TABLE 2.—Summary of the Average Effects of Sulfur Compounds on the Metabolism of Hemidiaphragms (Warburg series)[a]

Treatment	Concentration	Change in glucose uptake[b]	t	Change in glycogen content[b]	t	Change in oxygen uptake[b]	t
	N	µg/mg wet tissue/hr		µg/mg wet tissue/90 min		µl/mg wet tissue/hr	
TG..........	5 x 10^{-5}	0.38(0.48) ± 0.574	0.66	—0.24(—0.20) ± 0.222	1.08	0.02(0.05) ± 0.085	0.24
	5 x 10^{-3}	0.37(0.32) ± 0.441	0.84	0.50(0.51) ± 0.141	3.55*	0.30(0.22) ± 0.061	4.92**
MES........	5 x 10^{-5}	—0.05(0.04) ± 0.440	0.11	0.32(0.40) ± 0.142	2.25	0.29(0.33) ± 0.154	1.82
	5 x 10^{-3}	—0.09(—0.11) ± 0.460	0.19	—0.10(—0.19) ± 0.099	1.01	0.17(0.06) ± 0.141	1.20
Cysteine.....	5 x 10^{-5}	0.45(0.41) ± 0.543	0.83	0.10(0.12) ± 0.114	0.89	0.00(0.06) ± 0.212	0.00
	5 x 10^{-3}	0.37(0.36) ± 0.612	0.60	0.05(—0.01) ± 0.160	0.31	0.12(0.10) ± 0.079	1.52
Control (1)...	....	0.26(0.20) ± 0.167	1.56	0.08(0.15) ± 0.055	1.45	0.06(0.00) ± 0.062	0.97
Control (2)...	....	0.31(0.30) ± 0.184	1.68	0.06(0.00) ± 0.043	1.40	—0.06(0.05) ± 0.083	0.72

[a] The averages ± s.e. are based on the results with 7 paired hemidiaphragms. A negative mean difference indicates an increased response in the presence of test compound.

[b] The values in parentheses are the treatment mean differences adjusted for blocks (Warburg runs). For the comparison of two adjusted treatment means by the t test, the standard error in this instance is $\sqrt{2/7\ E_e\ [1 + (T\text{-}k)/T(k\text{-}1)]}$ based on the effective error variance of Table V; cf. Figure 1 for symbols.

* Significant at the 2% level of probability.

** Significant at the 1% level of probability.

TABLE 3.—Analysis of Variance of the Effect of Control, TG, MES and Cysteine, each at 5 x 10^{-3} N and 5 x 10^{-5} N on Hemidiaphragms (Warburg series)[a]

Source of variation	df	Change in oxygen uptake			Change in glucose uptake			Change in glycogen content		
		ss	ms	F	ss	ms	F	ss	ms	F
Replications (R)	6	0.37202	0.06200	0.69	36.55180	6.09196	6.74**	0.41600	0.06933	0.65
Treatments (adjusted)	7	0.51637	0.07377	0.82	1.67798	0.23971	0.26	2.73697	0.39100	3.68**
Blocks within (R)	7	1.73978	0.24854	....	1.89065	0.27009	....	1.72379	....	....
Intra-block error	35	3.13883	0.08968†	....	31.61617	0.90332†	....	3.71594	0.10616†	....
Total	55	5.76700			71.73660			8.59270		

[a] The average values for the differences in oxygen uptake, glucose and glycogen appear in Table IV.
** Significant at the 1% level of probability.
† Effective error variance (E_e).

compounds. No difference was observed between the effect of the sulfur compounds within each concentration on the glucose uptake. At 5×10^{-5} N, only a heterogeneous response was noted between treatments on glycogen content only, a slight elevation resulting with cysteine and DMA in contrast to a moderate decrease in the presence of MES, DTDG and TG. A marked depression in glycogen content with the higher concentration, 5×10^{-3} N, was distinct solely for TG.

The 'paired' *t* test is properly applied in these experiments as it was in the case of the tissue respiration studies (Spencer et al., 1964). Glucose uptake in the presence of 5×10^{-5} N TG was slightly decreased, while at the higher concentration, a more significant depression was observed. The average differences in glycogen content due to the presence of the five sulfur derivatives do not parallel the respective changes in glucose uptake except for TG, where a significant lowering in muscle glycogen was also observed. The two thiols, MES and TG at a level of 5×10^{-3} N, behaved differently as regards glycogen, the former compound increasing the over-all content as shown in Table 1.

This study was further amplified by the use of the Warburg apparatus with three of the agents, TG, MES and cysteine (concentrations: 5×10^{-5} N and 5×10^{-3} N). The general experimental conditions remained the same except that about 20 min were required for additional adjustments. Control solutions included for each test compound served not only as a check on the glucose concentration, but also toward correction of the manometric readings. As more than one Warburg run was necessary to include all test solutions, a balanced incomplete block design was selected as the most suitable for the experiment. An important feature of this procedure provides that each treatment will be tested an equal number of times concurrently with every other one and that an adjustment be applied to the treatment averages to correct for the influence of blocks (runs) in which they appear. It should be pointed out that no comparison could be made in the metabolic shaker series between the varied responses by glycogen to the two levels of MES or TG, both concentrations being studied separately. In the Warburg experiments, this effect was duplicated and the difference between the adjusted treatment averages found to be significant (*t* - values: 3.14 and 3.77 for MES and TG, respectively; $P < 0.01$).

Control treatments, namely, the differences between paired hemidiaphragms incubated in the absence of any sulfur compound, served to substantiate the reliability of the results. The variance or standard error attached to these treatments in regard to glucose uptake proved smaller than those observed with the test compounds. This finding would indicate that the response to the mercapto-acids is dependent on the individual pairs of hemidiaphragms investigated.

Glucose determinations were consistently dependent upon replications in both series. In the metabolic shaker experiment at 5×10^{-5} N, the mean glucose uptake for the control hemidiaphragms ranged 1.76-2.54 mg for the five replications, whereas the average of the control hemidiaphragms for each thiol treatment was 2.02-2.59 mg. The variability of glucose estimations affected equally all determinations per day, no interaction with treatments (T x R) being produced. Whether glucose determinations were sensitive to a technical factor or to animal variation (condition) could not be evaluated from these experiments. The corresponding average glucose uptake value was found to be 1.53 mg by Villee and Hastings (1949a) and Krahl and Cori obtained an average of 1.93 mg (1947).

The results of the present investigation possibly confirm one of the published *in vivo* observations. Thus, Freeman and coworkers (1956) demonstrated that the glycogen content of liver was markedly reduced following the injection of toxic doses of TG in mice treated with glucose. However, rat gastrocnemius muscle underwent little alteration but the amount of glucose employed in this instance was much higher. It would be of interest to ascertain whether an elevation in the amount of glucose in the incubation media would alleviate the depression in diaphragm glycogen, a point not investigated in the present study. This is proposed in view of the decreased toxicity noted by the Freeman group when glucose was administered together with TG to intact animals. Certainly, no correlation is justified between the present tissue results and parenteral toxicity data. In fact, MES, which is even more toxic than TG, did not impair glycogenesis but actually increased glycogen formation at the higher concentration.

Although it was thought that a similarity in metabolic action might exist among the four compounds, TG, MES, DMA and cysteine, because of the presence of at least one sulfhydryl group in each, this was not the case when they were compared at equivalent concentrations. Because of their divergent behavior, the over-all structure rather than the presence of the SH group as such must be the responsible factor. Also, no generalization can be advanced as yet relative to thiol configuration and muscle carbohydrate metabolic activity. That the observed effects with TG are also bound up with the SH group is evident from the qualitative differences resulting with the disulfide or oxidized form (DTDG). Of the sulfur compounds investigated, only cysteine is endogenous to the cell. From its innocuous nature at the relatively high level screened in this study, a low order of direct involvement in *in vivo* muscle glycolysis might be implied.

Summary

The influence of equivalent concentrations of thioglycolate, β-mercaptoethanesulfonate, α,α'-dimercaptoadipate, cysteine and dithiodiglycolate on carbohydrate metabolism of the rat diaphragm was ascertained. A phosphate-saline medium containing 110 mg % glucose was employed throughout. Incubation was carried out in a metabolic shaker for the comparison of the sulfur compounds at two levels, 5×10^{-5} N and 5×10^{-3} N. At the former concentration, no decisive difference between the effects of the sulfur compounds resulted. Thioglycolate, in

contrast to the other compounds, produced a definite depression in final glycogen content as well as a lower glucose uptake. β-Mercaptoethanesulfonic acid at the higher level, appeared to stimulate glycogenesis. Neither cysteine, dimercaptoadipate nor dithiodiglycolate at either concentration affected the final glycogen content or glucose utilization.

In a second series, the effect of thioglycolate, β-mercaptoethanesulfonate and cysteine were compared at the two concentrations employing the Warburg apparatus. Two control treatments were included to ascertain the normal variation and average difference between untreated paired hemidiaphragms. Glycogen content and oxygen uptake were depressed only in the presence of thioglycolate at 5×10^{-3} N. A difference in glycogen response to the two levels screened was specific for thioglycolate and β-mercaptoethanesulfonate.

Because of the divergent effects on carbohydrate metabolic activity noted with the sulfur compounds tested, the over-all configuration rather than the sulfhydryl group as such, constitutes a most important factor.

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PHENOLIC MANNICH BASES

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ABSTRACT.—The synthesis of several 2-bis (beta - hydroxyethyl) aminomethyl - *p*-substituted phenols, 2-bis(beta-hydroxypropyl)aminomethyl-p-substituted phenols, and their conversion to the corresponding nitrogen mustards, is reported.

DISCUSSION

In previous work (Weatherbee, 1956, p. 1138) condensation of equimole quantities of hydroquinone, formaldehyde, and N,N-iminodiethanol in methanol solution resulted in the isolation of a 60% yield of 2-N,N-Bis (beta-hydroxyethyl) aminomethylhydroquinone, but only a 23% yield of 2,5-Bis [N,N-bis (beta-hydroxyethyl) aminomethyl] hydroquinone was secured upon the interaction of hydroquinone, formaldehyde, and N,N-iminodiethanol in a 1 :2 :2 mole ratio, respectively.

In continuation of this work the condensations of *p*-substituted phenols, formaldehyde, and bis (beta-hydroxyalkyl) amines were investigated. Details of the experimental work are given at the end of this paper.

Reaction of *p-tert*-butylphenol, formaldehyde, and N,N-iminodiethanol in a mole ratio of 1 :1 :1 gave a salt of the expected Mannich base, 2-bis (beta-hydroxyethyl) aminomethyl - D - *tert*-butylphenol - hydro - *p-tert*-butylphenolate. The expected Mannich base apparently reacted stoichiometrically with the *p-tert*-butylphenol. Similarly when bis (beta - hydroxypropyl) amine was used in lieu of the N,N-iminodiethanol, the stoichiometric addition compound of 2-bis (beta-hydroxypropyl) aminomethyl-4-*tert*-butylphenol with *p-tert*-butylphenol was the only crystalline product isolated.

In view of the salt formation, condensations were carried out in alcoholic hydrochloric acid solutions; low yields of the Mannich base hydrochlorides or starting materials were obtained. Addition of dry hydrogen chloride to reaction mixtures of equimole quantities of amine, formaldehyde, and phenol after the usual reaction time without the removal of the solvents resulted in the isolation of tars and viscous materials. However, removal of the solvent from the condensation of *p*-substituted phenols, formaldehyde, and bis (beta-hydroxylalkyl) amines in methanol at 25° for 20 hours or at gentle refluxing for 2 hours gave oils. When the oils were dissolved in methanol followed by the addition of dry hydrogen chloride, the Mannich base hydrochlorides were secured. By use of this procedure the average yields of 2,5-Bis [N,N-bis (beta-hydroxyethyl) aminomethyl] hydroquinone were increased from 23% to over 60%, and the yields of other previously reported derivatives of hydroquinone (Weatherbee, 1956, p. 1138) were increased.

The hydroquinone derivative, 2,5,-Bis [N,N-bis (beta-hydroxyethyl) aminomethyl] hydroquinone, was used as an intermediate in the preparation of 2,5-Bis [N,N-bis (beta-chloroethyl) aminomethyl] hydroquinone hydrochloride, which is effective against Ca 755, L1210, Dunning Leukemia, Lymphoma 8, Ehrlich EF, Yoshida Hepatoma; and Walker 256 ascites, pulmonary and solid substaneous (Wilson, 1961, p. 199). Mannich bases prepared in this work have been submitted to the National Institutes of Health for evaluation against Walker 256 rat tumors, KB cell culture, and their routine three tumor-bearing animal screens (lymphoid Leukemia 1210, Adenocarcinoma 755, and Sarcoma 180).

The usual procedure (Raiziss, 1941, p. 3124) (Speziale, 1956, p. 2556) for converting beta-hydroxyalkyl amines to their corresponding beta-chloro derivatives with thionyl chloride involves the addition of the latter to a solution of the hydroxy alkylamines in chloroform, methylene chloride, benzene, or other inert solvent, followed by refluxing. The use of diethylene glycol dimethyl ether as a solvent has also been reported (Lyttle, 1958, p. 80). Only small yields of phenolic nitrogen mustards from the 2-bis (beta-hydroxyalkyl) amines were secured by this procedure. It was found convenient to add the thionyl chloride dropwise to the solid beta-hydroxyalkyl amine hydrochloride on an ice bath and permitting the reaction mixture to slowly warm to room temperature. In certain instances the reaction mixture was warmed to 35-40° after the addition of the thionyl chloride, but temperatures in excess of 40° resulted in the formation of tars and noncrystalline materials. Addition of thionyl chloride to the free bases (beta-hydroxyalkyl amines) gave somewhat lower yields than when the amine hydrochlorides were employed.

Reaction of 2-bis (beta-hydroxyethyl) aminomethyl-4-benzyloxyphenol with thionyl chloride at 30-35° resulted in the isolation of 2-bis (beta - chloroethyl) aminomethylhydroquinone hydrochloride rather than the desired 2-bis (beta-chloroethyl) aminomethyl-4-benzyloxyphenol-hydrochloride, the thionyl chloride or hydrogen chloride formed during the reaction readily cleaved the benzyloxy group.

Procedures

The C, H microanalyses were performed by Weiler and Strauss, Microanalytical Laboratory, Oxford, England. The N analyses were performed by Alfred Bernhardt Mikroanalytisches Laboratorium im Max-Planck-Institut fur Kohlenforschung, Ruhr, Germany. The temperatures are reported in degrees centigrade.

2,5-Bis [bis (beta-hydroxyethyl) aminomethyl] hydroquinone dihydrochloride.—To 420.6 g (4 mole) of N,N-iminodiethanol in 100 ml of methanol at 14-17° was added dropwise with stirring 216.2 g of 55% formaldehyde (4 mole) in methanol. After adding 220 g (2 mole) of hydroquinone, the mixture was stirred well for 5 minutes. The resulting solution was warmed at 30-40° for 2 hours and then at 45-50° for 2 hours. The solvents were removed by vacuum and the resulting oil was dissolved in 150 ml of methanol. Dry hydrogen chloride was bubbled through the solution until no further precipitate appeared to form. Upon filtration 470 g of white solid was secured. An additional 38 g was obtained by concentrating the filtrate at room temperature. Total crude yield was 508 g (60%), m.p. 198-200° (dec). After 4 recrystallizations from 90% methanol-water solution, the product melted at 208-209° (dec). (Analysis: Calculated for $C_{16}H_{30}Cl_2N_2O_6$: C, 46.05; H, 7.-24. Found: C, 46.35; H, 7.36).

2-Bis (beta-hydroxyethyl) aminomethyl-4-tert-butylphenol hydro-p-tert-butylphenolate.—To 7.5 ml of 37% formaldehyde (0.1 mole) was added with stirring over a period of 3 minutes 9.6 ml of N,N-iminodiethanol (0.1 mole) dissolved in 10 ml methanol at 15-16°. After adding 15 g of *p-tert*-butylphenol (0.1 mole) in 25 ml of methanol, the mixture was stirred for 5 minutes at 15-18° and then set aside in a stoppered flask for 22 hours at 25-28°. The solvents were removed by evaporation under a hood leaving a reddish-brown solid. Upon recrystallization from cyclohexane, the product weighed 15 g (72%), m.p. 97-99°. Two additional recrystallizations gave m.p. 100-101°. (Analysis: Calculated for $C_{15}H_{25}NO_3 \cdot HOC_6H_4C(CH_3)_3$: C, 71.90; H, 9.41; N, 3.36. Found: C, 71.73; H, 9.46; N, 3.20, 3.34).

2-bis(beta-hydroxypropyl)aminomethyl-4-tert-butylphenol-hydro-p-tert-butylphenolate. — Repetition of the above experiment using bis(beta-hydroxypropyl)amine in lieu of the iminodiethanol gave a 68% yield of 2-bis(beta-hydroxypropyl)aminomethyl-4-tert-butylphenol-hydro-p-tert-butylphenolate, m.p. 111-112°. (Analysis: Calculated for $C_{17}H_{29}NO_3 \cdot HOC_6H_4C(CH_3)_3$: C, 72.77; H, 9.73; N, 3.14. Found: C, 72.34, 73.19; H, 9.52, 9.66; N, 3.01, 3.17).

2-bis(beta-chloroethyl)aminomethyl-4-tert-butylphenol hydrochloride.—To 10 g (0.035 mole) of 2-bis (beta-hydroxyethyl)aminomethyl-4-*tert*-butylphenol hydrochloride cooled on an ice bath was added dropwise 15 ml of thionyl chloride. The mixture was allowed to slowly warm to room temperature and stand for 14 hours. The excess thionyl chloride was removed by vacuum leaving a viscous material which was dissolved in 20 ml of ethyl acetate containing a trace of ethyl alcohol. Upon cooling 9.2 g (75%) solid, m.p. 120-123° was removed by filtration. Three recrystallizations from ethyl acetate containing a trace of ethyl alcohol gave m.p. 140-142°. (Analysis: Calculated for $C_{15}H_{23}Cl_2NO \cdot HCl$: C, 52.87; H, 7.10; Ionic Cl, 10.40; N, 4.11. Found: C, 53.03; H, 7.36; Ionic Cl, 10.70; N, 4.04).

The following compounds were prepared under conditions similar to the formation of 2,5-bis(beta-hydroxyethyl)aminomethyl hydroquinone dihydrochloride:

2-bis(beta-hydroxyethyl)aminomethyl-4-bromophenol hydrochloride, m.p. 158°, yield 70%. Analysis: Calculated for $C_{11}H_{16}BrNO_3 \cdot HCl$: C, 40.45; H, 5.24; ionic Cl, 10.85. Found: C, 40.72; H, 5.33; ionic Cl, 11.04.

2-bis(beta-hydroxyethyl)aminomethyl-4-tertiarybutylphenol hydrochloride, m.p. 162-164°, yield 58%. Analysis: Calculated for $C_{15}H_{25}NO_3 \cdot HCl$: C, 59.30; H, 8.63; ionic Cl, 11.67; N, 4.61. Found: C, 59.64; H, 8.66; ionic Cl, 11.82; N, 4.41.

2-bis(beta-hydroxyethyl)aminomethyl-4-tertiaryamylphenol hydrochloride, m.p. 145°, yield 61%. Analysis: Calculated for $C_{16}H_{27}NO_3 \cdot HCl$: C, 60.46; H, 8.88; ionic Cl, 11.16; N, 4.40. Found: C, 60.56; H, 8.63; ionic Cl, 11.35; 11.17; N, 4.43.

2-bis(beta-hydroxyethyl)aminomethyl-4-benzyloxyphenol hydrochloride, m.p. 168°, yield 51%. Analysis: Calculated for $C_{18}H_{23}NO_4 \cdot HCl$: C, 61.10; H, 6.84; ionic Cl, 10.02. Found: C, 60.84; H, 7.13; ionic Cl, 10.27.

2-bis(beta-hydroxypropyl)aminomethyl-4-tertiarybutylphenol hydrochloride, m.p. 208-210°, yield 41%. Analysis: Calculated for $C_{17}H_{29}NO_3 \cdot HCl$: C, 61.52; H, 9.11; ionic Cl, 10.68. Found: C, 61.75; H, 9.00; ionic Cl, 10.91.

2-bis(beta-hydroxypropyl)aminomethyl-4-tertiaryamylphenol hydrochloride, m.p. 191-193°, yield 49%. Analysis: Calculated for $C_{18}H_{31}NO_3 \cdot HCl$: C, 62.50; H, 9.33; ionic Cl, 10.25; N, 4.05. Found: C, 62.44; H, 9.45; ionic Cl, 10.05; N, 4.00.

2-bis(beta-hydroxypropyl)aminomethyl-4-benzyloxyphenol hydrochloride, m.p. 171-173°, yield 37%. Analysis: Calculated for $C_{20}H_{27}NO_4 \cdot HCl$: C, 62.90; H, 7.39; ionic Cl, 9.29. Found: C, 62.71; H, 7.45; ionic Cl, 9.40.

The following compounds were prepared under conditions similar to the formation of 2-bis(beta-chloroethyl)aminomethyl-4-tertiarybutylphenol hydrochloride:

2-bis(beta-chloroethyl)aminomethyl-4-bromophenol hydrochloride, m.p. 175-176°, yield 78%. Analysis: Calculated for $C_{11}H_{14}BrCl_2NO \cdot HCl$: C, 36.34; H, 4.16; ionic Cl, 9.75; N, 3.85. Found: C, 36.11; 36.29; H, 4.23, 4.08; ionic Cl, 9.61; N, 4.14.

2-bis(beta-chloroethyl)aminomethyl-4-tertiaryamylphenol hydrochloride, m.p. 116-117°, yield 82%. Analysis: Calculated for $C_{16}H_{25}Cl_2NO \cdot HCl$: C, 54.32; H, 7.13; ionic Cl, 10.02; total Cl, 30.07. Found: C, 53.78, 54.65; H, 7.61, 7.79; ionic Cl, 10.32; total Cl, 29.35.

2-bis(beta-chloroethyl)aminomethyl-4-hydroxyphenol hydrochloride, m.p. 215-216°, yield 70%. Analysis: Calculated for $C_{11}H_{15}Cl_2NO_2 \cdot HCl$; C, 43.95, H, 5.37. Found: C, 44.41, H, 5.44.

2-bis(beta-chloropropyl)aminomethyl-4-tertiarybutylphenol hydrochloride, m.p. 162-163°, yield 59%. Analysis: Calculated for $C_{17}H_{27}Cl_2NO \cdot HCl$: C, 55.37; H, 7.65; ionic Cl, 9.62; N, 3.78. Found: C, 55.14; H, 7.84; ionic Cl, 9.70; N, 3.64.

2-bis(beta-chloropropyl)aminomethyl-4-tertiaryamylphenol hydrochloride, m.p. 150-152°, yield 73%. Analysis: Calculated for $C_{18}H_{29}Cl_2NO \cdot HCl$: C, 56.47; H, 7.90; ionic Cl, 9.26; total Cl, 27.79. Found: C, 56.10, 56.70; H, 7.62, 8.09; ionic Cl, 9.43; total Cl, 27.7.

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FOOD HABITS OF BOBWHITE QUAIL DURING JANUARY-MARCH IN SOUTHERN ILLINOIS

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ABSTRACT.—Bobwhite quail utilization of food items in winter was determined from 195 crops collected during January through March from southern Illinois. Plant materials comprised 84.2 per cent of the volume and animal matter 15.8 per cent; grit occurred in 12.8% of the crops and 12.3% were empty. Of 81 food items, 11 made up 1.0% or more by volume. These included corn 34.6%, lespedezas 16.1%, slugs 13.7%, soybean 7.2%, oaks 6.7%, sassafras 5.3%, desmodiums 2.7%, common ragweed 2.1%, wheat 2.1%, small wild bean 1.7%, and rushfoil 1.5%. During January, Korean lespedeza ranked first with 40.8% whereas corn ranked first (33.8%) in February and in March (43.6%). Grit occurred in 2.0%, 8.6%, and 24.3% of the crops during January, February, and March, respectively.

This research was conducted to determine foods utilized by bobwhite quail (*Colinus virginianus*) during January through March. It was anticipated that such data would permit an analysis of the effects of environmental conditions, such as weather and land use practices, on the dietary pattern of bobwhites during this season. For comparison, a previous study (Larimer 1960) established similar information for the fall season (November and December).

DESCRIPTION OF AREA

The region of southern Illinois included in this study incorporates the southern 34 counties. However, data to be presented include only nine counties (Massac, Union, Jackson, Williamson, Franklin, Hamilton, Perry, Washington, and Marion) which represent the central and southern portions of southern Illinois. This area is characterized by intermingled prairie conditions from the north, and the Ozark and Shawnee Hills from the south. The northern part, affected by recent glaciers, is level land characterized by a young topography with poor drainage. Most of the southern section, not affected by glaciers, has a hilly topography with serious erosion. According to Leighton, et al. (1948), two physiographic regions, Shawnee Hills Section and Mt. Vernon Hill Country, are represented by those counties where quail were collected.

The Shawnee Hills Section in general coincides with the unglaciated area and is represented by red and yellow podzolic soils (U. S. Department of Agriculture 1938) which are subject to severe erosion, resulting in submarginal and patch-type farming. Most of the bottomlands are composed of clay and are relatively unproductive; however, those originated from alluvial deposits are fertile. Corn, lespedeza, and soybeans are the chief crops, but fruit and vegetable production are important in local areas. Because of the erosible topography, 38 to 68% of cultivatable land is in hay or pasture, with 10% idle (Ross and Case 1956). Forests occupy about 26 to 41% of the land area (King and Winters 1952).

The Mt. Vernon Hill Country comprises the southern portion of the

Illinoisan driftsheet. The major soils are planosols derived from the action of glaciers and loess deposits and formed under the influence of permanently or seasonally poor drainage conditions (U. S. Department of Agriculture 1938). The surface soils are low in fertility and organic matter. Subsoils are heavy, tough, and impervious causing poor drainage and poor drought resistance. Corn and soybeans are the principal crops, with 6-10% of the land idle, 23-29% in pasture, and 17-32% in forest growth.

Three farming regions, General Farming and Dairy, General Farming, and General Farming and Fruit (Ross and Case 1956), were represented in the sample of quail crops collected. In the General Farming and Dairy region, wheat, corn, and soybeans comprise 29%, 13%, and 13%, respectively, of the cultivated land. Twenty percent of the cultivatable land is pasture and 7% idle.

In the General Farming area, erosion and poor soil drainage contribute to the pattern of land use. Corn and soybeans, 19% and 13%, respectively, are the most important crops; idle land comprises 15% and forest land 16 to 25%. The distribution of idle land and forest, plus the production of corn, soybeans, and Korean lespedeza contribute to good quail habitat in this area.

The southern tip of Illinois is the General Farming and Fruit area. As most of this lies within the boundaries of the Shawnee National Forest, woodland comprises 26 to 41% of the land area. Corn (22%) and soybeans (9%) are the important intertilled crops; hay (9%) and pasture (36%) are the main permanent cover crops. The rolling topography of the upland contributes to soil erosion and often results in patch farming that offers excellent quail habitat.

Southern Illinois is characterized by hot summers, mean temperature of 78°F in July, and cool to cold winters, mean temperature of 30°F in January (Page 1949). The average snowfall is approximately 10 inches, with most occurring in January, February, and December. Rainfall averages 40 to 46 inches per year with January, March, and April being the wettest months.

Materials and Methods of Analysis

During January, February, and March 1956, 195 quail crops were collected from 34 individual hunting trips. As trapping methods would require the use of bait that would appear in the crop analyses, quail were collected by regular hunting methods. Field notes, land use, cover utilization, activity and weather conditions, were recorded for each bird. Harvested birds were tagged with such data as date, sex, age, weight, and time of kill and frozen upon return from the hunt.

Identification of various food items were made by utilizing the reference collection of the Cooperative Wildlife Research Laboratory. Unknown seeds were sent to Dr. Alexander Martin, Research Biologist at Patuxent Research Refuge, Laurel, Maryland, for identification. Insect nomenclature was based on Jaques (1947), gastropods after Baker (1939), and plants according to Jones (1950). The Southern Illinois University Statistical Service calculated total volume and frequency of occurrence. Volume of individual food was based on determinations employed by Larimer (1960).

Presentation and Discussion of Data

The 195 crops for winter yielded 81 specific food items of which animal matter comprised 15.8% by volume and plant material 84.2%; 12.3% of the crops contained no food. In comparison, Larimer's (1960) study for fall showed 187 food items in 4606 crops from birds harvested in 34 counties in southern Illinois; 9.5% of the crops were empty. Larimer reported 93.9% plant material by volume and 6.1% animal matter. Differences in number of food items and quantity of plant foods utilized during the two seasons suggest fewer items and more reliance on animal matter in winter. However, the significantly greater number of crops for fall may have an important bearing on the nature of these results. It seems likely that availability of a variety of foods would be reduced in winter but the explanation of a 100% increase in consumption of animal matter is not so readily apparent.

Six plant families, grass (Gramineae), legume (Leguminosae), beech (Fagaceae), laurel (Lauraceae), composite (Compositae), and spurge (Euphorbiaceae), comprised 1.0% or more by volume and accounted for 82.3% of the total quantity of all foods. The grasses ranked first with a combined volume of 37.0% with corn being the major contributor; other grasses were of minor importance. The green leaves of cheat (*Bromus* spp.) and small grain were ingested in small quantities. Noticeably absent were the foxtail grasses (*Setaria* spp.) which during the fall hunting season of 1950 and 1951 comprised 1.0% by volume (Larimer 1960). The seeds of foxtail grasses fall early and are probably not readily available in late winter. The legumes accounted for 30.0% of the volume and yielded the largest number of individual species. Korean lespedeza ranked first, but soybean, small wild bean, and common lespedeza were consumed in relatively large amounts. Legume leaves accounted for a large measure of the green leafy material. The Fagaceae, represented by oaks only, ranked third by volume with 6.7%. Acorns encountered consisted of fragments suggesting that utilization was made of remains left by the feeding activities of other animals. The Lauraceae, ranking fourth with 5.3%, was represented by sassafras only. The abundance of sassafras along fencerows and as an early woodland invader of the fields makes it a rather widely distributed and available food throughout southern Illinois. The composites accounted for 2.1% of the volume with common ragweed being the chief representative. Lance-leafed ragweed (*Ambrosia bidentata*), probably the most common species of this group in southern Illinois, made up only 0.03% of the total volume of all food items. Although this species was widely available, the data suggest that it was rarely utilized in proportion to its availability, indicating that it possibly is not acceptable as quail food. The Euphorbiaceae ranked sixth with a per-

TABLE 1.—Twenty-four Top-ranking Food Items Taken by Bobwhite Quail During January-March, 1956 Compared to Findings of Larimer (1960) for November-December, 1950 and 1951, Southern Illinois.

Food Item	This Study		Larimer (1960)	
	Percent Frequency of Occurrence	Percent Volume	Percent Frequency of Occurrence	Percent Volume
Corn *Zea mays*	23.1	34.6	28.9	27.8
Korean and common Lespedezas *Lespedeza stipulacea* and *striata*	36.8	16.1	42.2	8.7
Slugs Philomycidae	15.9	13.7	6.9	2.8
Soybeans *Glycine max*	7.2	7.2	22.1	22.4
Acorns *Quercus* spp.	5.1	6.7	9.6	7.2
White sassafras *Sassafras albidum*	6.1	5.3	5.2	3.8
Desmodiums *Desmodium* spp.	6.7	2.7	12.1	2.9
Common ragweed *Ambrosia artemisiifolia*	9.7	2.1	26.4	4.6
Wheat *Triticum aestivum*	3.6	2.1	4.5	5.5
Small wild bean *Strophostyles leiosperma*	10.8	1.7	12.4	1.0
Rushfoil *Crotonopsis elliptica*	1.5	1.5	1.7	0.2
Sumacs *Rhus* spp.	3.6	0.7	1.0	0.05
Partridge pea *Cassia fasiculata*	6.7	0.7	2.4	0.06
Vetch *Vicia* sp.	1.0	0.6	0.04	Trace
Horse nettle *Solanum carolinense*	2.6	0.5	1.4	0.08
Ground beetles Carabidae	5.1	0.4	4.4	0.2

Food Item	This Study		Larimer (1960)	
	Percent Frequency of Occurrence	Percent Volume	Percent Frequency of Occurrence	Percent Volume
Spiders Arachnida	2.1	0.4	3.3	0.2
Legume leaves Leguminosae	18.5	0.3	....	....
Insect larvae Insecta	2.6	0.3	3.0	0.3
Leafhoppers Cicadellidae	5.6	0.3	3.8	0.2
Amber snails Succinia	5.6	0.2	0.8	0.03
Ants Formicidae	1.5	0.2	3.7	0.2
Stink bugs Pentatomidae	2.0	0.2	2.3	0.2
Bidens *Bidens* spp.	3.0	0.2	18.9	1.4

cent volume of 1.6. Rushfoil accounted for the largest percentage, followed by hogworth (*Croton capitatus*) which contributed a minute quantity.

Twenty-one different animal food items were represented; other than slugs, the majority were of little significance in the total volume (15.8%). Ground-beetles (Carabidae) were the chief insects taken, followed by leaf hoppers (Cicadellidae) and stink-bugs (Pentatomidae), with a percent volume of 0.4, 0.3, and 0.2, respectively. The quantity and occurrence of slugs as a winter food is difficult to explain, as the availability of the insects and other animal life was expected to be limited in winter.

Of the 12.3% of empty crops, several were collected in the morning and also during periods when snow and ice were on the ground, which may have prevented the quail from leaving sheltered areas to feed.

Of 81 specific food items identified, only 11 comprised 1% or more of the total volume (Table 1). Cultivated plants yielded a major portion of the food as six farm crops accounted for 59.6% of the total volume. Corn, the most utilized food by volume (34.6%) and second by frequency of occurrence (23.1%), is the major farm crop grown in southern Illinois; mechanical picking results in considerable waste grain available after harvest. By volume, Larimer (1960) found that corn ranked first in the fall food habits of quail (Table 1). Korean and common lespedeza ranked second by volume (16.1%) and first by frequency of occurrence (36.8%). Larimer (1956) found these two lespedezas to rank third volumetrically and first in frequency. These two studies suggest that lespedezas were not only a desired food but were probably readily available. Slugs ranked third by volume (13.7%) and fourth by frequency of occurrence (15.9%); they did not appear during days of deep snow or below freezing temperatures. Larimer (1960) ranked slugs ninth by volume (2.8%) in the fall food habits. Soybean, fourth volumetrically (7.2%) and seventh by frequency of occurrence (7.2%), probably reflects agricultural importance and availability. In the fall foods, soybeans ranked second by volume and fourth by occurrence (Larimer 1960); the rapid deterioration of this food probably accounts for its decreased occurrence in winter. Oaks, ranking fifth by volume (6.7%) and frequency of occurrence (5.1%), occur throughout the study area and were considered readily available to the bobwhites. Larimer found acorns to rank fourth (7.2%) in the fall foods. Sassafras was sixth (5.3%) by volume in the winter and seventh (3.8%) by volume in the fall (Larimer 1960); the percent frequency of occurrence was approximately the same for both seasons. Desmodiums totaled 2.7% by volume in the winter and 2.9% (Larimer 1960) in the fall food habits. These legumes, although not widely abundant, occur generally in woodland and brushy habitats and as a weed associated with fallowed fields following agricultural crops. Common ragweed, ranked eighth (2.1%) by volume and sixth by frequency of occurrence, was abundant in cultivated lands, fallow lands, roadsides, pastures, and newly abandoned fields. In the fall food habits, common ragweed ranked sixth (4.6%) by volume and third by frequency of occurrence (Larimer 1960). Wheat, ranked fifth (5.5%) by Larimer (1960) in the fall food habits, is an important crop of southern Illinois, but yielded only 2.1% of the total food volume in winter. The use of wheat in winter seemingly reflects its general availability as result of weathering. Small wild bean (1.7% by volume), an annual found on dry and sandy soils, was relatively abundant (as indicated by frequency of occurrence, 10.8%) in abandoned fields. Rushfoil, which has a restricted distribution because of its growth requirements, yielded 1.5% by volume. The fall food habits showed wheat, small wild bean, and rushfoil with volumes of 5.5%, 1.0%, and 0.2%, respectively (Larimer 1960). Legume leaves had a frequency of occurrence of 18.5%, ranking third by occurrence, but had a percent volume of only 0.3%; these were not recorded in the fall diet.

Food Utilization by Months. Of 36 food items taken by the 51 quail collected in January, only 9 provided a volume greater than 1.0% (Table 2). Korean lespedeza, corn, and soybean were the most prevalent foods; sumacs and horse nettle were consumed only in January which probably reflects the effect of snow on the dietary pattern. The utilization of animal matter during January was the lowest recorded for the 3 months,

Table 2.—Comparison by Months of Principal Food Items Consumed by Quail During January, February, and March, Southern Illinois, 1956.

Food Items	January (51 crops)	February (70 crops)	March (74 crops)
	Per Cent Volume	Per Cent Volume	Per Cent Volume
Corn	27.8	33.8	43.6
Korean lespedeza	40.8	1.0	1.5
Soybean	16.8	3.0	0.9
White sassafras	3.5	9.9	2.0
Slugs	2.5	21.0	18.3
Wheat	1.3	0.4	5.0
Desmodiums	1.0	0.2	7.7
Common ragweed	0.9	0.8	5.1
Small wild bean	0.3	3.8	0.9
Vetch	0.0	0.0	2.0
Sumacs	2.1	0.0	0.0
Horse nettle	1.4	0.0	0.0
Partridge pea	0.1	0.0	2.2
Oaks	0.0	16.2	3.1
Rushfoil	0.0	4.1	0.0
All other food items	1.7	5.9	7.7
Grit (percent frequency)	2.0	8.6	24.3
Empty (percent frequency)	13.7	11.4	12.2

probably due to weather conditions; slugs yielded only 2.5% of the volume. Grit was recorded in 2.0%; 13.7% of the crops were empty.

During February, 51 food items were consumed by 70 birds collected, with corn, slugs, and acorns ranking highest (Table 2). Acorns which ranked third in February were not present in January. Korean lespedeza dropped from 40.8% in January to 1.0% in February. Rushfoil was not present in January but ranked fifth in February. Animal matter accounted for a larger percentage of the February foods with slugs alone yielding 21.0%. Grit had a percent frequency of 8.6 compared to 2.0 in January. Empty crops had a frequency similar to that in January.

Of the 59 food items consumed by 74 quail collected in March, 11 had a volume of over 1.0% (Table 2). Corn, slugs, and desmodiums were the most commonly used. Desmodiums, common ragweed, and wheat were more important in March than either January or February. Korean lespedeza, which ranked first in January, fell to eighth place in February and tenth in March. The use of the more perishable foods such as soybeans and small wild beans declined considerably in March. More crops contained grit in March than either January or February; empty crops had a percent frequency of 12.2%.

Food items consumed during each month seem to show a general trend of food availability. As the season progressed, availability of quail foods change from general abundance and many varieties in the fall (Larimer 1960) to scarcity and few varieties in late winter. Climatic conditions may alter the pattern of food availability and result in a forced change in the quail diet. Also, seeds with thin seed coats will deteriorate and become less abundant than the seeds with hard coats (Bookhout 1954). Those seeds that tend to fall to the ground early will not be as available as those that fall gradually over longer periods of time. A larger percentage of the crops collected in January were collected during days when the snow was on the ground; thus, the amounts and kinds of food items consumed were affected by more adverse weather conditions than those of February and March.

Average weights of birds decreased as the winter progressed, dropping from 180 grams in January to 177 in February and to 170 grams in March. The average weight for the combined period of January to March was 175 grams. Such weight losses may have reflected the availability as well as the quality of foods.

Food Utilization According to Soil Regions. Quail crops were collected from two major soil regions, the planosols and the red and yellow podzolic soils. The planosols were represented by 131 crops from seven counties and the red and yellow podzolic soils by 64 crops from two counties. Except for a variation in the number of seeds of individual plant foods, there appeared to be little difference in the kinds of foods (Table 3). This was similar to that

TABLE 3.—Comparison of the Dietary Pattern of Bobwhite Quail From Planosols and Red and Yellow Podzolic Soils, Southern Illinois, 1956.

Food Items	Planosols (131 crops)	Red & Yellow Podzolic (64 crops)
	Percent Volume	Percent Volume
Corn	39.3	21.1
Korean lespedeza	13.7	19.1
Slugs	9.1	27.0
Soybean	8.8	2.6
White sassafras	6.8	1.2
Oaks	5.0	11.8
Desmodiums	3.6	0.0
Common ragweed	2.6	0.6
Small wild bean	2.2	0.5
Rushfoil	2.0	0.0
Sumacs	1.0	0.0
Wheat	0.8	3.7
Vetch	0.0	2.2
Ground beetles	0.2	1.0
All other food items	5.1	9.6
Grit (percent frequency)	12.2	14.1
Empty (percent frequency)	10.7	15.6

reported by Korschgen (1952) for quail from different soil regions in Missouri. For the red and yellow podzolic soils in southern Illinois, slugs ranked first with corn and Korean lespedeza second and third, respectively. In crops from the planosols, corn ranked first, followed by Korean lespedeza and slugs. More wheat and less soybeans were noted from the red and yellow podzolic than from the planosols. Vetch occurred in the podzolic region but was absent from the planosol region, while desmodiums and rushfoil which ranked among the top ten food items in the planosol area were not recorded from the red and yellow podzolic region. This was probably due to the greater abundance of the latter two plants in fallow and idle land of the planosol region making it more available than in the red and yellow podzolic area. Quail collected from the red and yellow podzolic region had an average weight of 176 grams while those from the planosols averaged 1 gram less.

Food Utilization According to Sex and Age. The sex ratio of the available sample of birds was 52.8% females and 47.2% males. Young birds showed 54.3% females and adults 45.7%. The juvenile birds made up 84.0% of the total sample.

A comparison of foods utilized by adults and juveniles showed some variation but no really significant difference. A comparison of food habits of males and females revealed some difference between the sexes. Slugs and sumacs yielded 22.7% and 1.7%, respectively, of the volume for males; only 7.9% and 0.1%, respectively, were recorded for females. White sassafras showed 8.1% for females and 1.2% for males. Theoretically, because a covey acts as a group there should have been few differences in food items consumed by males and females. There is the possibility that female quail in preparation for egg-laying were stimulated to alter their diet.

No apparent difference in weight was noted between the males or females, nor between adults and juveniles. The average weight for females was 174 grams, for males 175 grams, for adults 176 grams, and for juveniles 175 grams.

Food Utilization According to Time of Kill. Of the total, 100 birds were collected in the morning and 95 in the afternoon. Analyses indicate no great difference in the foods consumed by quail collected in the morning as compared with those killed in the afternoon, although some exceptions were noted. Desmodiums showed 5.1% for the afternoon and 0.1% for the morning. Soybean, corn, and common ragweed ranked higher in the morning, while Korean lespedeza, oaks, rushfoil, vetch, and partridge pea were significantly higher in the afternoon. There seems to be no logical reason to explain this pattern of food utilization. Quail killed in the morning weighed 176 grams—3 grams more than the birds killed in the afternoon (173 gm).

Food Utilization and Weather. The temperature in southern Illinois was below average for January 1956. On January 19th a cold wave moved into the southern part of the State and continued through the remainder of the month (U. S. Department of Commerce 1956). Several inches of snow fell on January 18th and

TABLE 4.—Comparison of the Dietary Pattern of Bobwhite Quail Collected During January When Snow was 3 inches in Depth and When Snow was 3 inches or less in Depth, Southern Illinois, 1956.

Food Items	Over 3 Inches of Snow (21 crops)	Under 3 Inches or no Snow (30 crops)
	Percent Volume	Percent Volume
Soybeans	56.3	0.0
Corn	30.1	26.9
Sumacs	6.5	0.2
Horse nettle	4.8	0.0
Korean lespedeza	1.2	57.6
Sweet clover (*Melilotus alba*)	0.3	0.0
Legume leaves	0.3	0.5
White avens (*Geum canadense*)	0.2	0.0
White sassafras	0.0	5.0
Slugs	0.0	3.6
Wheat	0.0	1.9
Desmodium	0.0	1.4
Common ragweed	0.0	1.3
All other food items	0.4	1.8
Grit (percent frequency)	0.0	3.3
Empty (percent frequency)	28.6	3.3

19th and was followed by a moderate snowfall on the 29th. There was a greater total snowfall in January than in any other January since 1945; although, the total depth at any one time never exceeded 6 inches. As January was considered to be the only month with sufficient snowfall and low temperatures to possibly alter the quail food habits, it was selected as a representative to evaluate the effect of snow and freezing temperatures on food utilization.

Crops for January were divided into two groups according to whether they were collected when the snow was over 3 inches in depth and 3 inches or less (Table 4). Three inches was chosen arbitrarily as a depth that would sufficiently cover seeds on the ground so as to alter quail food patterns. As deep snows tend to cover seeds that lie on or close to the ground, availability of certain foods is probably restricted and quail have less variety as well as quantity from which to obtain their dietary needs.

A change in the quail dietary pattern was noted when snow was on the ground. Comparison of food items consumed during days when the snow was over 3 inches and days when there was less than 3 inches of snow, revealed that soybean, sumacs, and horse nettle were more heavily used when snow covered the ground (Table 4). These species tend to stand above the snow and thus probably were more available to the birds. Also, the seed pods and seeds remained on these plants and were not covered by the snow. During the study, the only time horse nettle and sumacs were taken in any quantity was when snow was on the ground, thus they might be classed as starvation foods. Damon (1949) reported that quail starved to death after a heavy snowfall even though crops of dead birds were filled with sumac seeds. Field observations during this study showed that quail were feeding in sumac thickets in addition to standing soybeans and stubble around the edge of harvested fields. In the fall Larimer (1960) found that soybean, cowpea, and purple meadow rue were utilized more heavily during periods of deep snow.

The utilization of Korean lespedeza dropped from 57.6% by volume to 1.2% during "snow days". White sassafras ranked third in January during "no snow days", but was not present in any crops during periods of deep snow. Corn appeared rather constant and ranked second during both conditions of snowfall. The mechanical harvesters apparently left some corn that was available above the level of the snow.

Twenty-one crops collected in January when the snow was over 3 inches in depth revealed only 16 different species in comparison to 28 species from 30 crops during the same month when there was less than 3 inches. No animal matter or grit was consumed during periods of deep snow; slugs ranked fourth in January when there was 3 inches or less of snow. Empty crops had a 28.6% frequency of occurrence for "snow days" compared to 3.3% for days with little or no snow. This occurrence of empty crops, plus the fact that quail lost weight during periods of snow, would indicate that excessive snowfall is a critical problem in the existence of quail. Quail collected when the snow was over 3 inches deep averaged 174 grams during January, while those taken when the snow was less than 3 inches, averaged 184 grams. These data suggest that the manipulation of factors to increase the abundance of suitable plants to provide food during deep snow would enhance the survival of quail.

Quail crops were analyzed according to whether they were collected during days with temperatures above or below 32° F. January was used as a representative as it was the only month with a sufficient number days with average temperatures below freezing. As snowfall and low temperatures were closely allied, the dietary pattern during low temperatures tended to reflect the same foods as those utilized when snow depth was 3 inches or more.

During the days that had an average temperature above freezing, volumetrically, Korean lespedeza (49.8%) ranked first, followed by corn (31.6%), white sassafras (6.3%), and slugs (4.5%). For the period of freezing temperatures, soybean (38.6%) ranked first with Korean lespedeza (29.1%) and corn (22.9%) second and third, respectively; sumacs (4.5%) and horse nettle (3.2%) were fourth and fifth. It could not be determined whether sumacs and horse nettle were utilized because of the low temperatures or because days of low temperature and snowfall were closely synchronized. Korean lespedeza showed considerable variation in utilization during above (49.8%) and below (29.1%) freezing temperatures; however, there was not so great a difference as between periods of snow (57.6%) and no snow (1.2%). No animal matter except an occasional insect larvae (.3%) was consumed during periods of intense cold. Empty crops showed a 20.6% frequency of occurrence during freezing temperatures, compared to no empty crops during above freezing temperatures; empty crops may reflect snowfall or they might point out the fact that quail do not move to feed as early or as much on cold days. There was a slight difference in weight between birds collected during periods of below freezing weather (179 grams) compared with those obtained during above freezing weather (181 grams). This difference could either reflect snow fall or empty crops where birds did not feed as readily or regularly during cold weather.

Food Utilization and Land Use. In an effort to determine the extent to which the food habits of quail were associated with land use practices, an attempt was made to classify quail crops as being representative of either cultivated land, wasteland, or mixed farmland. Because the exact range of any one covey was not nown, the basis for classification was determined by where quail were harvested. If a bird was obtained in cultivated fields, fencerows or other areas associated with farming practices, the birds were considered as representative of cultivated land. Birds killed on land where there was

Table 5.—Comparison of Food Items Occurring in the Crops of Bobwhite Quail Collected From Cultivated Land, Wasteland, and Mixed Farmland, January-March, Southern Illinois, 1956.

Food Items	Cultivated Land (131 crops)	Wasteland (42 crops)	Mixed Farmland (17 crops)
	Percent Volume	Percent Volume	Percent Volume
Corn	38.9	18.0	49.5
Slugs	13.7	14.2	15.4
Soybean	10.8	1.2	0.0
Korean lespedeza	8.0	32.7	22.4
White sassafras	5.7	2.6	9.7
Oaks	5.2	6.8	0.0
Desmodiums	5.2	6.8	0.0
Common ragweed	2.9	1.1	0.0
Wheat	2.6	1.7	0.0
Small wild bean	2.3	0.6	0.4
Sumacs	1.1	0.2	0.0
Rushfoil	0.0	6.5	0.0
Partridge pea	0.0	3.0	0.0
Ground beetles	0.2	1.2	0.0
Spiders	0.0	1.1	0.9
All other food items	4.6	9.2	1.3
Grit (percent frequency)	11.5	11.9	0.0
Empty (percent frequency)	13.7	4.8	0.0

no evidence of farming practices in the general area, such as wasteland, abandoned fields, or woodlands, were recorded as being from wasteland. Quail collected in wasteland associated with cultivated fields were classified as coming from mixed farmland.

In cultivated lands where corn ranked first, slugs second, and soybean third (Table 5), 11 items made up more than 1.0% of the diet. Crops from the wasteland area revealed 13 items with a volume greater than 1.0%; of these Korean lespedeza, corn, slugs, oaks, and rushfoil were the more abundant items. In the mixed farmland, crops (17) were probably insufficient to determine with certainty the food pattern; however, corn, Korean lespedeza, slugs, and white sassafras were the only food items that had a volume greater than 1.0%.

Of the 11 items occurring in crops from cultivated land, desmodiums, small wild bean, and sumacs did not rank in the top items in the wasteland area (Table 5). According to Bookout (1954) desmodiums were associated with plowed lands, while sumacs were associated with permanent cover such as wasteland. Small wild bean was found more frequently in idle lands. Thus it would seem that sumacs and small wild bean should have been more utilized in wasteland areas; as previously pointed out, the use of sumacs was associated with snowfall. Of the 13 top food items utilized by quail from wasteland, rushfoil, common lespedeza, partridge pea, ground beetles, and spiders were the only foods not represented in volumes over 1.0% in crops from cultivated areas. Rushfoil, lespedezas and partridge pea are normally associated with abandoned land. Ground beetle and spiders could be associated with either but might be expected to occur in wasteland in larger numbers.

It can be concluded from the data that quail depend heavily, regardless of the habitat, upon cultivated crops for their subsistence as corn ranked high as a food item in all categories of land use (Table 5). Soybean occurred over 1.0% by volume in cultivated and wasteland groups. Due to modern farming operations considerable waste grain remained in the fields and was readily available. As feeding habits of quail were governed by what was available, cultivated seeds associated with adequate cover were frequently used. Korean lespedeza, although grown for hay and pasture, was usually associated with wasteland because of its persistence and ability to spread. Whether birds were utilizing the wasteland as dependable sources of food or as cover was not established. In some areas, doubtlessly quail depended on wasteland for cover and probably subsisted on no cultivated foods. But, where cultivated crops occur within the cruising radius of a quail covey, these crops were probably consumed in relationship to their availability.

A slight difference was noted in the weight of birds from different land use areas. Quail from cultivated lands averaged 2 grams heavier than those from wasteland, while birds from mixed and wasteland averaged 7 grams heavier than those from cultivated lands. This would indicate that cultivated and wasteland intermingled offers better environment for quail.

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POLLEN ANALYSIS OF SOME PLEISTOCENE SEDIMENTS FROM ILLINOIS

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ABSTRACT.—The pollen content of sediments collected in a strip mine south of Canton, Illinois tends to confirm the intra-Illinoian stratigraphic placement of the deposit. High percentages of spruce and pine pollen found in the samples and larch wood are typical of sediments dating from glacial ages. A warming trend may be revealed by presence of deciduous pollen near the middle of the sediments. It seems likely that the sediments are from a late Illinoian interstadial and may be contemporaneous with the Roby silt. The extensive Pennsylvanian deposits over which the glaciers advanced account for the presence of numerous Paleozoic spores in many of the samples.

While attempting to locate and reexamine a peat layer studied by Voss (1939, p. 523), another well developed organic deposit was found south of Canton, Illinois. The deposit dates from a late Illinoian interstadial (Wanless, 1957), and underlies the till bounded by the Buffalo Hart moraine. This report summarizes a pollen analytical investigation of the sediments of this Illinoian interstadial interval and provides some inferences concerning the vegetation and climatic conditions of the subage.

LOCATION OF THE CANTON DEPOSIT

The Illinoian interstadial deposit was exposed, when visited on June 4, 1960 and on May 12, 1963, near the base of the bank of an abandoned strip mine located in the Buckheart Mine less than two miles south of Canton, Illinois. The exposure is near the center of the south line of N½ sec. 11, T6N, R4E in Fulton Co., Illinois.

STRATIGRAPHY

The organic silt, herein referred to as the intra-Illinoian silt in the Canton section, is exposed in the north bank of an old strip mine near the mouth of a north-trending gully. The exposure is near the west edge of the Mine Haulage Road, one mile north of the State Aid Road intersection. During the three years intervening between the visits to the site, considerable erosion has occurred, altering the way in which the sediments are exposed. The base of the organic intra-Illinoian silt is only one foot above the surface of the water in the strip mine pit. The silt lies between two tills, with the deeply leached Sangamon Soil developed in the overlying till. The Sangamon Soil is overlain with loess.

A summary of the Canton section is given below:

	Thickness (ft.)
Peoria and Roxana Loess, Gray	10.0
Sangamon Soil, in Illinoian (Buffalo Hart) till, reddish color, pebbles and cobbles near upper contact	
Illinoian till (Buffalo Hart), gray blocky	12.0
Sand, fine above, coarse in lower two inches	1.1
Silty clay, black; organic (samples 17, 18)	0.6
Silt, gray with brown organic (?) streaks; wood, up to 1″ diameter, in middle; some rounded pebbles (samples 8-16)	3.0
Silt, brown-black; blocky fracture (samples 4-7)	1.0

Sand, gray with dark streaks (samples 1-3) 0.8
Sand, brown with occasional coal inclusion 0.3
Illinoian till, gray.........Base of unit not exposed

It is likely that the intra-Illinoian silt in the Canton section is contemporaneous with the Roby silt which is exposed in this region and contains molluscan remains (personal communication, W. Hilton Johnson and George E. Ekblaw).

Samples for pollen analysis were collected on June 4, 1960 from those sediments which appeared likely to have organic content, including the gray sand, brown-black silt, gray silt, and black silty clay. Samples 1-3 are from the gray sand, samples 4-7 from the brown-black silt, samples 8-16 from the gray silt, samples 17 and 18 from the black silty clay.

Procedure

Some samples were processed soon after collection, others in 1963. Each was dissolved in 7% HCl, centrifuged, and treated with HF. Samples were then washed in dilute HCl again and suspended in a saturated solution of $ZnCl_2$ in HCl. The pollen-bearing portion was skimmed off the top of the $ZnCl_2$ and washed in water and then in glacial acetic acid. Samples were then heated in a solution of nine parts acetic anhydride and one part sulfuric acid. Finally the sediment was washed with water and again with 50% glycerine before embedding in glycerine jelly. Several samples collected in May of 1963 were also processed. They seem to be the equivalent of samples 17 and 18 of the 1960 collection and yielded no pollen.

The counting was done under 100X magnification and identification was confirmed under 420X or 1,000X under oil. Of the samples which contained much pollen a minimum of five slides was counted and at least one slide of the other processed samples was examined (samples 10, 12, 14, 16 and 18). Samples 9, 11, 13, 15 and 17 were not processed. Many spores were found, some resinous and others not clearly so, which closely resemble spores found in coal (see Fig. 1, G and H). Most of them are very unlike what would be expected in Pleistocene sediments, but one type has not been distinguished from the modern spores of *Selaginella*. These spiny tetrahedral spores which were occasionally found in tetrads may represent *Selaginella* in the local flora, but since *Selaginella* spores are not usually found in large numbers it is suspected that the palynomorph is from the coal flora and it was omitted from the percentage calculations (see Fig. 1, E). The number of other spores was only approximated. They are presumed to have been derived from erosion of the nearby coal beds at the time of deposition. It is possible that there was also some secondary deposition (rebedding) of conifer pollen; some of these grains are in perfect condition, whereas the rebedded ones are so badly battered that they are barely identifiable. Since the latter are found in numbers proportionate to the numbers of Paleozoic spores, they are considered to be of secondary deposition and are disregarded.

Results

Several pieces of wood, measuring up to six inches long, were found

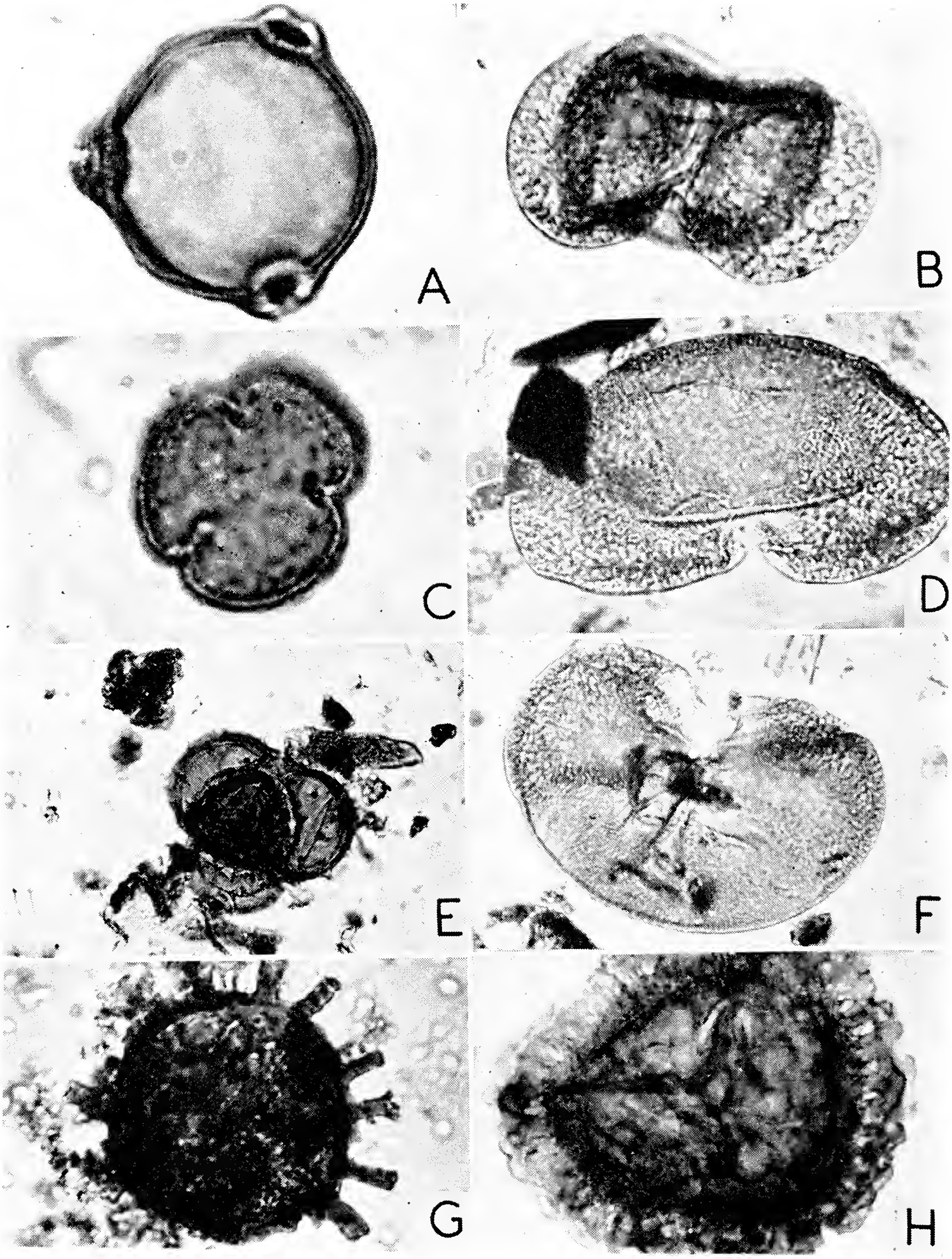

FIGURE 1.—Several pollen and spore types recovered from the Canton deposit. A. Birch (*Betula*) pollen, 30 μ, 1000X. B. *Pinus* (pine) pollen, body length 45 μ, 420X. C. Oak (*Quercus*) pollen, 37 μ, 450X. D. Large *Picea* (spruce), body length 82 μ, 420X. E. Tetrad of *Selaginella*-type spores, 420X. F. Small *Picea* (spruce), body length 65 μ, 420X. G. Paleozoic spore, 45 μ, 450X. H. Trilete Paleozoic spore, 66 μ, 1000X.

three feet above the basal till in the gray silt. They were identified by microscopic examination as larch (*Larix*) wood. The samples taken near this wood, however, yielded little pollen; significant amounts were obtained only from the gray sand and brown-black silt in the lower portion of the section. Table 1 summarizes the percentages of each type of pollen found in samples 3 through 8, and lists the total number of grains counted in each sample. Spruce and pine account for the greatest percentage of each sample and the preponderance of conifer pollen is even greater in terms of absolute numbers since the samples yielding the most pollen also have the highest percentages of conifer pollen. The spruce pollen in these samples was found in two size ranges, one group about 80μ (body length) and the other group about two-thirds

TABLE 1.—Pollen From the Intra-Illinoian Silts of the Canton Section. Percentages are computed on basis of total pollen and spores counted.

	Sample Number					
	3	4	5	6	7	8
Coniferous Trees						
Larix (larch)	2%	6%	7%	3%	16%	7%
Picea (spruce)	48%	43%	12%	31%	6.5%	
Pinus (pine)	40%	46%	30%	63%	45%	76%
Deciduous Trees and Shrubs						
Betula (birch)			2%			
Carpinus-Ostrya (blue beech-ironwood)		1%	2%			
Carya (hickory)			8%	.5%		
Juglans (walnut)	.5%		6%		3%	
Myrica (sweet gale)			1%			
Quercus (oak)	1%		18%		16%	
Tilia (basswood)						3%
Herbaceous Plants						
Ambrosia (ragweed)			5%			
Gramineae (grass)	1%		4%			
Solidago (goldenrod)			1%			
Ferns	6%	4%	4%	2%	12%	13%
Total Pollen Counted	194	99	102	208	31	29

as large (see Fig. 1, D and F). Pollen from deciduous trees is encountered in each sample represented here, but occurs in substantial amounts only in sample 5, in which it accounts for 37 per cent of the pollen counted (see Fig. 1, A and C). The notable exception to this is the oak pollen in sample 7, which accounts for 16 per cent of the pollen in this sample. Fern spores, of the smooth reniform type, were found in these samples, along with variable numbers of spores resembling *Selaginella*—from 3 in sample 8 to 77 in sample 6. The latter were omitted from Table 1 for reasons stated above.

The amount of pollen in the samples drops sharply above sample 6, samples 10 through 18 yielding only occasional conifer grains. Sample 18 yielded Paleozoic spores exclusively. Of the samples shown in Table 1, those yielding the most pollen also contained the most spores and degraded pollen grains.

Discussion

The general preponderance of spruce pollen indicates that the climate at the time of deposition was much cooler than it is now, which is to be expected during a glacial interstadial. We have speculated that the large spruce pollen may represent *Picea rubens*, the red spruce which occurs now in the Appalachian Mountains. The percentage of pine pollen, although higher than the percentage of spruce, probably represents fewer pine trees, since each pine produces excessive quantities of pollen. The scarcity of herbaceous pollen suggests that the surrounding vegetation was a closed forest. The Illinoian interstadial forest which contributed the pollen assemblage was probably dominated by spruce, and to a lesser degree, by pine. Deciduous trees, notably oak, were found either intermixed with the coniferous forest on certain sites, or the pollen was derived from surrounding regions by wind dissemination. The general trend of climate seems to be warming up to the time period represented by sample 5. In this sample the number of pollen grains of deciduous trees nearly equalled the number of conifer pollen grains. This appears to have been followed by a cooler episode, although it may have been warmer than the initial period, judging by the higher ratio of pine to spruce pollen.

Acknowledgments

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EVIDENCE FOR PARTIAL HYBRID CLEISTOTHECIA IN *ASPERGILLUS RUGULOSUS*

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ABSTRACT.—Modification of an established technique for the identification of hybrid cleistothecia in *Aspergillus rugulosus* has led to the detection of partial hybrid cleistothecia. Partial hybrid cleistothecia contain asci which develop following the fusion of identical nuclei as well as asci which develop following the fusion of genetically dissimilar nuclei. As a result, the expected distribution of segregating genes is obscured. Random ascospore analyses from cleistothecia which contain only asci developing following the fusion of genetically dissimilar nuclei, yield the expected distribution of segregating genes and substantiate the existence of partial hybrids.

In the course of investigations with *Aspergillus nidulans,* Hemmons, et al. (1953) were able to determine by random ascospore analyses of a particular cross that approximately 15 percent of the cleistothecia in the cross contained asci of more than one kind, i.e., they yielded colonies giving a yellow to green conidial color ratio that was significantly different from the expected 1:1. Cleistothecia which contain selfed and crossed asci are termed "partial hybrid" cleistothecia. In the cross of *Aspergillus rugulosus* discussed in this paper, 15 percent of the cleistothecia analyzed were hybrid. However, only 4 percent of cleistothecia examined contained asci of more than one kind. This paper provides evidence for the existence of partial hybrid cleistothecia in *Aspergillus rugulosus.*

MATERIAL AND METHODS

The source of the isolate of *Aspergillus rugulosus* used as well as the techniques for the selection and identification of mutants have been given (Coy and Tuveson, 1964).

The minimal medium employed throughout this investigation was Czapek's solution agar (Difco). The concentration of supplements added to the medium for identification of nutritional markers have been presented (Tuveson and Garber, 1959). The complex medium used was potato dextrose agar supplemented with 5 percent yeast extract (Difco). For the dry weight experiments, the agar was filtered out of the complex medium and the liquor was then supplemented as required and sterilized. Thirty ml volumes of this liquid were pipetted into Petri dishes and inoculated with approximately 100 ascospores/plate. After 4 days incubation, the resulting mycelium was collected or dried, weighed filter paper. The paper plus mycelium was then dried for 24 hours in an oven maintained at 60° C and then reweighed. The total weight minus the weight of the filter paper was used as a measure of growth under the nutritional conditions employed.

All cultures were grown in incubators maintained at a temperature of 37° C.

To distinguish cleistothecia containing asci of more than one kind (partial hybrids) from those containing asci of selfed origin which failed to show segregation of the markers distinguishing the parentals (only the yellow marker or only the green marker being recovered) or those cleistothecia giving yellow and green in a 1:1 ratio, 0.1 ml aliquots of 3 ml saline solutions containing single crushed cleistothecia were plated; preserving the major part of each suspension in the refrigerator. The suspensions from which the aliquots had given the expected or aberrant ratios for color markers after two days incubation were further plated on non-selective medium (complex medium + 0.5 mg/ml lysine) on a scale sufficient for the complete analysis of all segregating genes.

Experimental Results and Discussion

Table 1 presents data showing the results of random ascospore analyses of a cross in *Aspergillus rugulosus* in which two cleistothecia gave a greatly decreased number of ascospores producing colonies having the color characteristics of one of the parentals. This phenomenon had not been detected in previous analyses when loopfuls of ascospore suspensions were streaked onto complex medium to establish hybridity (Coy and Tuveson, 1964), but became apparent when 0.1 ml aliquots of saline containing crushed cleistothecia were dallied onto plates for the analyses described here.

Of the 44 cleistothecia harvested from the cross represented in Table 1, seven were determined to be hybrids. Of these seven, two gave highly distorted color ratios. These two cleistothecia were analyzed as to color and auxtrophy of ascospores with two cleistothecia whose ascospores produced colonies giving the expected color ratio. In such analyses, each random ascospore represents an independent observation as it is taken from a large population. The results of these analyses are presented.

Each entry represents a separate cleistothecium. The numbers, 2 and 5, represent the number of days each crushed cleistothecium was refrigerated in saline. These periods of refrigeration apparently had no effect on the viability of the ascospores.

Partial hybrids 2 and 5 each gave an excess of wild type alleles for the markers of one parent. Those spores requiring para-amino-benzoic acid (pab), isoleucine (iso), and lysine (lys) are much fewer in number than expected. In contrast, those requiring proline (prol) are in great excess. Each of these markers is expected to yield a 1:1 ratio of prototrophic to deficient colonies. The appropriate statistical procedure for assessing the significance of a deviation from a 1:1 ratio would be the Chi square test. In testing the goodness of fit to a 1:1 ratio, both of the ''partial'' hybrids gave highly significant deviations.

No such deviation from the expected 1:1 ratio was found in hybrids 2 and 5. These cleistothecia gave mutant to wild type alleles with approximately equal frequencies of every marker with the exception of the proline marker. Ascospores requiring this amino acid are recovered with a reduced frequency. Experimental evidence indicates that the proline mutant is inhibited by the presence of lysine in the medium. Dry weight determinations for a Y, -prol (green, -proline) mutant grown on liquid potato dextrose agar plus yeast extract (PDA ≁YE); PDA ≁

TABLE 1.—Random Ascospore Analysis of "Partial" Hybrid and Hybrid Cleistothecia in *Aspergillus rugulosus*. Cross: yellow, -isoleucine, -lysine, -para-aminobenzoic acid, non-producer[a]/green, -proline, producer.

		Wild-type alleles recovered at each locus analyzed							
		green conidia	+iso	+pab	+prol	+lys	producer	Total no. colonies analyzed	X no. colonies/plate[b]
Partial hybrid 2	obs	138	146	140	74	145	151	208	33.4
	exp	104	104	104	104	104	104		
	X^2	22.2	33.8	24.8	17.2	32.2	42.4		
Partial hybrid 5	obs	158	159	152	27	157	128	182	44.1
	exp	91	91	91	91	91	91		
	X^2	86.2	89.0	72.2	76.8	83.6	27.4		
Hybrid 2	obs	102	102	89	130	119	98	203	36.1
	exp	101.5	101.5	101.5	101.5	101.5	101.5		
	X^2	0.004	0.004	3.0	16.0	6.4	0.2		
Hybrid 5	obs	96	97	88.	114	91	98	195	48.6
	exp	97.5	97.5	97.5	97.5	97.5	97.5		
	X^2	0.04	0.004	1.8	5.4	0.8	0.004		

[a] Non-producer = inability to synthesize an as yet unidentified antibiotic.

[b] Mean number of colonies on complex medium plates from which random colonies were picked for analysis.

YE / 0.5 mg/ml of isoleucine; and PDA ≠ YE / 0.5 mg/ml lysine support this hypothesis. The mean values for the dry weights on these three media were respectively: .2539 gm, .2505 gm, and .2405 gm. The probability that the dry weight of the mycelium from these treatments differed significantly was calculated using a "T" test on the means. The difference in dry weight of the mutant grown on the lysine supplemented medium as compared to the mycelial weights obtained from the other two experimental conditions was statistically significant at the 5 percent level suggesting inhibition of growth of the proline mutant by lysine. Another noticeable deviation is found in the prototrophs for lysine in hybrid 2. These are somewhat in excess; however the Chi square value, 6.4, is of borderline significance. Its probability is less than one in twenty, but greater than one in a hundred. It does not approach the deviations observed in the case of the partial hybrid cleistothecia. Further, in hybrid 5 no such deviation is observed suggesting the deviation for the lysine marker in hybrid 2 is random.

In each case where the green to yellow color ratio was other than 1:1, the green predominated. Although to date few partial hybrids with these markers have been found, there is good evidence from the general growth patterns of the respective mutants that the green color would be expected to predominate. The green mutant produces abundant cleistothecia after 7-10 days incubation. This indicates that the green mutant is capable of selfing. However, the yellow mutant selfs very poorly and produces few cleistothecia even after extended periods of incubation. At best the mycelium of the yellow mutant yields only scattered clusters of cleistothecia. It is assumed that the green mutant, being capable of selfing, enters partial hybrid formation readily. Analyses of individual asci have not been undertaken, but such analyses may give additional information as to the formation of partial hybrids. Nevertheless, it is apparent that not all the hybrid cleistothecia formed in *Aspergillus rugulosus* represents true hybrids. Some must be the product of at least two nuclei.

Acknowledgments

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VERTEBRATE REMAINS FROM AN HISTORIC ARCHAEOLOGICAL SITE IN ROCK ISLAND COUNTY, ILLINOIS

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ABSTRACT.—An historic Sauk-Fox Indian site in Rock Island County, Illinois yielded over 5,500 bones identified to genus and/or species. A minimum of 13 species of fish, 7 turtles, 28 birds and 21 species of mammals were recorded. Mammals, particularly deer, were the most important food source followed by fish and turtles. Seemingly, birds were used primarily to make bone artifacts and ornaments. Animals from the site, that are now extinct or extirpated in Illinois, include trumpeter swan, wild turkey, passenger pigeon, ivory-billed woodpecker, raven, elk, black bear, bobcat, otter, bison, fisher, mountain lion and gray wolf.

The Crawford Farm Site (Ri 81) located 1½ miles east of Milan, Rock Island County, Illinois, is one of the few historic sites in this state that has been thoroughly investigated by professional archaeologists. This historic Sauk-Fox site, thought to have been occupied from about 1790 to 1810, as evidenced by the types of trade silver, glassware, metal utensils and beads recovered, is situated on the south bank of the Rock River, approximately five miles from the confluence of the Rock and Mississippi rivers. Extensive tracts of flood plain timber, upland forest and brush areas, as well as the rivers, provided ideal habitat for a variety of animals that were used extensively by these Indians.

Initial investigation and periodic excavation began in 1957. Through the combined efforts of Dr. R. W. Slack, Davenport, Iowa, and Mr. Dale F. Holmgrain and Mr. Burton Hansen, East Moline, Illinois, a considerable quantity of faunal material was recovered and made available for study. During the fall of 1958, and summers of 1959 and 1960, archaeological field parties under the directorship of Dr. John C. McGregor and Dr. Elaine Bluhm, Department of Anthropology, University of Illinois, systematically excavated larger sections of the village where a large amount of additional refuse was encountered. Earth-moving equipment uncovered still more bone in the spring of 1961. I would like to express my appreciation to these individuals for permitting me to study and report on these vertebrate remains.

Most of the faunal materials recovered in this village were found in refuse pits; a small quantity occurred in the midden debris, while a few pieces were apparently interred with human burials. Over 15,000 bone remains were examined during this study and of the total, approximately 36% were identifiable to the genus and/or species level. Four classes of vertebrates were represented; included were a minimum of 13 species of fish, 7 species of turtles, 28 species of birds, and 21 species of mammals. The identified species and the number of remains of each are listed in Table 1.

DISCUSSION OF SPECIES

Fishes. Nearly 28% of the identifiable remains from this site were

TABLE 1.—Vertebrates Identified from the Crawford Farm Site, Illinois (1957-1961).

Species	Number of Identified Remains	Percent
FISHES	1,569	27.59
Channel Catfish, *Ictalurus punctatus*, and/or Blue Catfish, *I. furcatus*	509	8.96
Fresh-water Drum, *Aplodinotus grunniens*	354	6.23
Buffalofish and Suckers: Catostomidae	158	2.78
Gar, *Lepisosteus* sp.	138	2.42
Buffalofish, *Ictiobus* spp.	137	2.41
Smallmouth Buffalofish, *Ictiobus bubalus*, and/or Black Buffalofish, *I. niger*	107	1.88
Sturgeon: *Acipenser* sp.	44	.77
Bass, *Micropterus* sp.	28	.49
Sucker, *Catostomus* sp.	22	.38
Redhorse, *Moxostoma*, sp.	18	.32
Flathead Catfish, *Pylodictis olivaris*	16	.28
Longnose Gar, *Lepisosteus osseus*	13	.23
Bass, Sunfish, Crappie group: Centrarchidae	7	.12
Sauger and/or Walleye, *Stizostedion* sp.	6	.11
Northern Pike, *Esox lucius*	6	.11
Shortnose Gar, *Lepisosteus platostomus*	4	.07
Blue Catfish, *Ictalurus furcatus*	2	.03
TURTLES	1,361	23.96
Soft-shelled Turtle, *Trionyx* sp.	768	13.52
Turtle: *Pseudemys, Chrysemys, Graptemys, Emydoidea* group	273	4.81
Turtle spp.	111	1.95
Snapping Turtle, *Chelydra serpentina*	90	1.58
Pond Terrapin, *Pseudemys scripta*	69	1.21
Map Turtle, *Graptemys geographica*	23	.40
Blanding's Turtle, *Emydoidea blandingi*	10	.18
Painted Turtle, *Chrysemys picta*	6	.11
Map Turtles, *Graptemys* sp.	6	.11
False Map Turtle, *Graptemys pseudogeographica*	5	.09
BIRDS	172	3.00
Trumpeter Swan, *Olor buccinator*	28	.49
Swan, *Olor* spp.	25	.44
Meadowlark, *Sturnella* sp.	14	.24
Turkey, *Meleagris gallopavo*	13	.23
Passenger Pigeon, *Ectopistes migratorius*	10	.18
Duck spp.	10	.18
Canada Goose, *Branta canadensis*	10	.18
Teal, *Anas* sp.	7	.12
Passerines	5	.09
Prairie Chicken, *Tympanuchus cupido*	5	.09
Bald Eagle, *Haliaeetus leucocephalus*	5	.09
Sandpiper, Scolopacidae	3	.05

Species	Number of Identified Remains	Percent
Ivory-billed Woodpecker, *Campephilus principalis*	3	.05
Goose spp.	3	.05
Red-shouldered Hawk, *Buteo lineatus*	3	.05
Wood Duck, *Aix sponsa*	3	.05
Mallard, *Anas platyrhynchos* (probably)	2	.03
Blue and/or Snow Goose, *Chen* sp.	2	.03
Long-billed Curlew, *Numenius americanus*	2	.03
Raven, *Corvus corax*	2	.03
Hawk sp.	2	.03
Red-tailed Hawk, *Buteo jamaicensis*	2	.03
Marsh Hawk, *Circus cyaneus*	2	.03
Pigeon Hawk, *Falco columbarius*	2	.03
Duck Hawk, *Falco peregrinus*	1	.02
Sparrow Hawk, *Falco sparverius*	1	.02
Great Blue Heron, *Ardea herodias*	1	.02
Least Bittern, *Ixobrychus exilis*	1	.02
Sandhill Crane, *Grus canadensis* (probably)	1	.02
Lesser Scaup or Ring-necked Duck, *Aythya* sp.	1	.02
Double-crested Cormorant, *Phalacrocorax auritus*	1	.02
American Coot, *Fulica americana*	1	.02
Domestic Chicken, *Gallus gallus*	1	.02
MAMMALS	2,578	45.38
White-tailed Deer, *Odocoileus virginianus*	2,030	35.74
Raccoon, *Procyon lotor*	158	2.78
Beaver, *Castor canadensis*	147	2.58
Elk, *Cervus canadensis*	108	1.89
Canid, *Canis* sp., probably Dog, *C. familiaris*	36*	.63
Black Bear, *Ursus americanus*	28	.49
Horse, *Equus caballus*	16	.28
Gray Squirrel, *Sciurus carolinensis*	12	.21
Squirrel, *Sciurus* sp.	7	.12
Bobcat, *Lynx rufus*	6	.11
Muskrat, *Ondatra zibethica*	6	.11
River Otter, *Lutra canadensis*	6	.11
Striped Skunk, *Mephitis mephitis*	4	.07
Cottontail, *Sylvilagus floridanus*	3	.05
Fox Squirrel, *Sciurus niger*	3	.05
Common Mole, *Scalopus aquaticus*	2	.03
Bison, *Bison bison* (probably)	1	.02
Fisher, *Martes pennanti*	1	.02
Mountain Lion, *Felis concolor*	1	.02
Badger, *Taxidea taxus*	1	.02
White-footed Mouse, *Peromyscus* sp.	1	.02
Gray Wolf, *Canis lupus* (probably)	1	.02
Totals	5,680	99.93

* Plus two additional complete, and one partially complete, dog burials.

fish. The quantity of fish bones recovered, as well as the variety of species represented, attest to the significance of this group as a source of food to these Indians. More than 1,500 of the approximately 6,000 fish bones excavated were identified, and 32% of the bones were those of the catfish (*Ictalurus* spp.). Separation of channel and blue catfish on the basis of osteological remains is often difficult and uncertain; determination of the blue catfish was based on the size of a pectorial fin spine and a section of lower jaw. This jaw came from a fish that probably weighed between 65 and 75 pounds. The majority of *Ictalurus* bones came from fish weighing 4 to 8 pounds; the eating quality of these fish is excellent and the Indian utilized them extensively.

Approximately one-fourth of the identified fish remains were those of the fresh-water drum, a species common in the Mississippi River and its larger tributaries. In comparing the pharyngeal bones and otoliths from this site with reference specimens of known weights, the majority of drum taken by these Indians weighed between 5 and 10 pounds. Most of the fish utilized by these people were, considering the species involved, large; this was especially true in the case of buffalofish and suckers. Like the catfish and drum, the catostomids (particularly the buffalofish) were abundant during this time period and, as a group, comprised nearly 22% of the identifiable fish remains from this site.

Few of the so-called game fish—that is, northern pike, bass (*Micropterus*), walleye—were taken. This may be indicative of the species complex and abundance of fish then inhabiting the Rock and Mississippi rivers and of the fact that the Indians caught fish in direct proportion to their availability and abundance. Judging from present-day population studies (for example, Barnickol and Starrett, 1951), the drum, catfish and catostomids greatly exceed the "game" species numerically (with possible local exceptions of the small centrarchids—sunfishes, crappie, bluegill) in the Mississippi River. However, the factor of selective fishing, based on the predominance of bones of the larger, meaty fish and the paucity of the small fish bones and those of game and other species, should be considered. The absence of bowfin (*Amia calva*) remains is of interest and suggests the possibility that the Indian disdained the use of this common but, by modern standards, unedible species. However, gar were apparently eaten and these fish are also considered less than desirable. In any case, the Indians occupying this site had available to them a variety and an abundance of fish which formed an important part of their diet.

Turtles. At least seven species of turtles were identified from the faunal samples recovered at the Crawford Farm Site and the remains of these are of interest from several points of view. Bones of soft-shelled turtles were the most numerous, constituting over 56% of the turtle remains. Many of these bones were from extremely large specimens and are probably referable to *Trionyx ferox*. A majority of the pond terrapin, map and snapping turtle bones were also those of large individuals. It is apparent that, as a group, they were especially desirable and sought after as a preferred food.

Of the more than 1,300 turtle bones recovered, none showed evidence of having been worked and/or used for any purpose. Utilization of turtle shells, especially the carapace for bowls, is a well-known trait of the prehistoric Indians of Illinois (Parmalee, 1957) and in some instances it appears that they may have been valued as much for this reason as for food (Fowler, 1959). The total absence of box turtle remains at this site—the carapace of *Terrapene* being especially adaptable for modification as a dish or bowl—and the quantity of unworked shell from numerous large specimens of aquatic forms, leaves little doubt but that turtles served as a valuable food and were hunted solely for that purpose.

Birds. Compared with the quantity of fish, turtle or mammal bones recovered at this site, avian remains were numerically few. Only 3% of the total number of identified bones from the Crawford Farm Site were those of birds. Birds were evidently hunted, but the infrequency of remains in the refuse pits and midden debris suggests that little use was made of them as food. The variety of species represented is noteworthy, but the number of bones of each is small (Table 1), with a total count of less than 120 specifically identifiable remains. Waterfowl (ducks, geese, swans) accounted for 53% of the total (31% swan). Although birds were probably eaten, the variety of "non-edible" species represented (particularly the raptors), and the number of worked bones, suggests that birds were often obtained for uses other than food.

One of the more interesting aspects of the avian materials was the utilization of swan bones for ornaments and/or tools(?) by these Indians. Over 80% of the swan bones recovered, primarily humeri (at least 12 individuals), exhibited evidence of having been cut, scraped, polished and/or engraved. A similar use of swan bones had been made by the prehistoric Middle Mississippi Indians once occupying the Cahokia Site (Parmalee, 1957, 1958), located along the Mississippi River approximately 185 miles south of the Crawford Farm Site. Typically, the ends of the humeri were cut off and the shaft was either sectioned for use as beads or left entire. Most of these whole shaft sections appeared polished and several had been elaborately engraved. In most cases their function is somewhat problematical, although in one instance Mr. Dale Holmgrain recovered a cut swan humerus which had apparently served as a whistle. The only record of the sandhill crane from this site was a section of the humerus that had been cut in a similar fashion as those of the swans.

Another bird bone artifact of special note, fashioned from the ulna of a bald eagle, was found by Mr. Holmgrain in a refuse pit. The proximal one-fourth of the ulna had been cut off and a hole drilled in the distal end. A small triangle had been cut out of the shaft (as was the case in the above mentioned swan humerus whistle) approximately 3½ inches from the distal end; this artifact had almost certainly been used as a whistle.

In addition to the remains of the trumpeter swan, a species now extirpated in Illinois, those of the passenger pigeon, long-billed curlew, raven, and ivory-billed woodpecker are noteworthy. The passenger pigeon is now extinct and although it migrated through Illinois in tremendous numbers, relatively few bones have been encountered thus far in archaeological sites. The limited number of raven and curlew records have also been recorded (Parmalee, 1958).

At this site, two carpometacarpals (in all probability from the same bird) of the raven were found in a refuse pit by Dr. Slack. This wing bone supports the large primary flight feathers and, at sites where these bones have been found associated with the burial complex (e.g. Banks Site, Arkansas; Parmalee, 1959a), it is apparent that the wings had been of special significance being used as fans, or possibly as arm ornaments or decoration. Although our specimens were found in a refuse pit, they may have originally been used in the same or a similar capacity. Bray (1961) and Wittry (1962) describe the occurrence of raven remains with human burials; heads and wings were apparently used as parts of a headdress and for decoration.

Remains of the ivory-billed woodpecker at this site are of zoological interest if it can be assumed that the birds were taken locally. Parts of one upper and two lower jaw sections were recovered; one of the lower sections was found with the nearly complete upper bill and these were probably from the same bird. The other section of the bill occurred in a different pit. The only other record of this woodpecker in Illinois is a tarsometatarsus found at the Cahokia Site (Parmalee, 1958). If these remains from the Crawford Farm Site were from birds killed locally, their presence would extend the known range of this species approximately 185 miles further north in western Illinois. However, the possibility exists that these remains of bills had been part of a headdress or pipe decoration, or had been used as another type of ornament, in which case the birds could well have been obtained elsewhere.

The bones of at least seven species of raptors, from such a numerically small sample of avian remains, may be of significance and bear out the idea that "Probably numerous species of birds such as hawks, owls, eagles and cranes were taken for their plumage rather than for food" (Parmalee, 1957). Swanton (1946) has discussed the various uses to which the feathers, beak and claws of raptors were put and their importance to the historic Indians of the southeastern United States. The variety of "non-edible" birds represented in this faunal sample and the quantity of worked bones, coupled with the sparse remains of ducks, geese and the turkey—food species occurring most commonly in prehistoric sites—suggests that birds were obtained more for their plumage(?) and bones rather than for food.

Mammals. The kinds of mammals utilized by these historic Indians differs little from those used by prehistoric cultural groups; typically, the white-tailed deer served as the basic meat staple. Eighty percent of the identifiable mammal remains were those of deer (35% of the total), and of the 5,100 unidentifiable large mammal bone fragments, most were probably referable to *O. virginianus*. Considering the size of the sample, the number of elk remains was high (108) and this large animal was probably killed whenever available. The black bear was taken in limited numbers (probably in relation to its abundance) and, unlike the prehistoric groups to whom the bear was of special significance (Parmalee, 1959b), was sought primarily for food and/or its hide.

Remains of the raccoon and beaver were the second and third most abundant bones, comprising approximately 12% of the total. Both animals were probably eaten and, at least in the case of the beaver, it is reasonable to assume (based on early historic accounts, for example, Thwaites, 1911) that the pelts were bartered to the whites for trade goods. The quantity of beaver remains (28% of the total) found at an historic Fox site (Bell Site) in Wisconsin (Parmalee, 1963) also suggested a beginning of intensified fur trapping activity. It is of interest to note that at least four pelves of the beaver, as shown by the smoothed and worn inner edges of the obturator foramen, had been used as a tool, possibly for the processing of leather (thong strop?) or as a fiber shredder. Also worthy of note were two black bear jaws found in refuse pits; a large, wedge-shaped section had been cut out of the rami and, although its use is questionable, these jaws may have served a similar function.

In addition to the domestic dog, remains of which were found in several refuse pits (including three intentional burials), these Indians also had the horse. However, bones of the horse were few in number, a minimum of one animal being represented, so the value of the horse and the use to which it was put is a matter of speculation. If these Indians had retained numerous animals, they were certainly taken with them when these people departed or were driven from this site. The nearly complete absence of bison at the Crawford Farm Site is noteworthy, since the animal was, by this time, not uncommon in the western sections of the state. Possibly the bison was not present locally and, with the abundance of deer and other food animals close at hand, extended hunting trips for them were unnecessary. Perhaps only the meat of animals killed some distance from the village (Iowa?) was brought back.

A variety of other mammals were taken, but the paucity of remains of each would indicate they were of no major importance in the food economy of these people. A complete ulna of the mountain lion was recovered in addition to part of a scapula of a large canid (probably gray wolf) and several bones of the bobcat; bones of these large predators are of interest in that they indicate the Indian occasionally made use of such carnivores for food(?) and/or for their hides. These remains also serve as indicators of the early historic distribution of such species now extirpated in Illinois. One of the most interesting records to come from this faunal sample was the partially complete fisher skull found with a human burial by Mr. Holmgrain. Quite possibly this skull was part of a medicine bag, but whether the animal had been taken locally, or brought down from the north by the individual, is a matter of speculation (Parmalee, 1961).

Summary

In evaluating the vertebrate remains from this historic site, it is apparent that numerous native species of fish, turtles, and mammals constituted the major food items and that the white-tailed deer served as the basic meat staple. Hunting was probably done on a selective basis with, for example, the larger catfish, drum, buffalofish, suckers and turtles being preferred. Probably the beaver and possibly other mammals as well were hunted or trapped for their pelts which were exchange for European trade goods. Birds were not a major source of food, but probably were hunted more for the use of their bones and plumage in the manufacture of ornaments and decorations.

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Manuscript received April 23, 1964

NEWS AND COMMENTS

Just a gentle threat—you members had better start sending in news or you will have nothing but comments to read.

Some inquiries have been made about the length of the abstracts that accompany articles in the Transactions. There are no limits. Abstracts should be adequate; that is to say, the title and the abstract should inform the busy investigator about the paper. If the magnitude of usefulness of an abstract is of such order that it serves as a substitute for the paper, then throw the paper away and publish the abstract.

While I am on the subject of length of printed matter, let me get one more subject off my chest. Authors who terminate their papers by stating that "space and time do not permit . . . etc." induce a state of mind in me that resembles that of a truculent wart-hog. The associate editors and I reserve the right to decide whether or not a paper is too long. Again, "adequate" is the word to describe the length of a paper. I know some authors are puzzled over what I delete and what I ask to be added to a paper. If I have any rule that governs such decisions, I guess it would be "What has the problem at hand to do with the title of the paper?" I might as well cite a couple more rules: the reader deserves some consideration, and good Anglo-Saxon English beats scientific jargon any day as a means of communication. That last rule gets me into more trouble. I have heard that I ruin the style of the author and make him appear as an "amateur" in the eyes of his friends because he does not match the "scientific writing" of the peers and compatriots in his field. Glory be! I hope I do, and I hope the readers not in his field appreciate it. Such thoughts are based on the idea that the Transactions are to be published in the best manner possible within the limits of our budget and for all of our readers.

Figure 1 is an example of how to type a manuscript for the Transactions. Our "Academy Historian" is the only author who can take privilege with this format. Don't forget to look on the inside of the back cover of a recent issue when preparing a manuscript.

Last comment: Papers do not have to be presented at the annual meeting in order to be published. We accept manuscripts from members any day of the year.

A GUIDE FOR TYPING MANUSCRIPTS FOR

ILLINOIS ACADEMY OF SCIENCE PUBLICATIONS

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ABSTRACT.-- This is the format for preparing manuscripts to be submitted to the Illinois Academy of Science.

Start here without more ado. Double space everything. Do not hyphenate words at the end of a line. Write out and capitalize the words table and figure every time. Tables should be on separate pages. Legends for figures should be on a separate page. The format for legends and tables should be like those seen in recent issues. Center headings should be centered and capitalized as in the example below:

DISCUSSION

Authors' names should be capitalized in the Literature Cited section. Side headings should be indented, principal words capitalized, and italicized thus:

The Use of Italics and Other Styles of Type. Mark other type styles, such as "bold face", with a light pencil.

LITERATURE CITED

APPLE, J., and W. MULE. 1929. Distilling made easy. Printing Office. Chicago. 439 pp

FIGURE 1.—A sample page showing how to type a manuscript for the Transactions.

NOTES

NOTES ON THE ALGAL FLORA OF KNOX COUNTY, ILLINOIS

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ABSTRACT.—Studies of the algal flora in two widely separated locations in Knox County, Illinois have increased the number of algal taxa known for that county to sixty-nine.

The algal taxa reported in the following checklist are the result of surveys conducted during 1963 in two widely separated locations in Knox County, Illinois: Lake Storey, situated one mile north of Galesburg on U.S. Route 150 and Green Oaks, the 760 acre Knox College Field Station, located three miles south of Victoria.

Lake Storey is a small, artificial impoundment that was constructed in 1928 by the Atchison, Topeka, and Santa Fe Railroad. Green Oaks consists largely of tailings and water filled trenches of coal mining operations which were curtailed around 1941. Since acquiring the land, an attempt has been made to restore the area to a more natural state. The algal forms reported in the checklist from this location were identified from plankton samples obtained during a recent limnological survey conducted in the station's waters.

The algal flora of Knox County is only poorly known with but a single, apparent, published record, *Euglena viridis*, in existence (Britton, 1944). Houdek (1923) reported, in a survey of the flora of Lake Knox, ten different algal genera but failed to commit any to species. During the intervening years, little, if any, algological research of a taxonomic nature has taken place in the county. With the forms presented in the subsequent checklist the total number of algal species including varietal forms recorded for Knox County now stands at sixty-nine.

ANNOTATED CHECKLIST OF SPECIES

Nomenclature follows that of Prescott (1963) and Tiffany and Britton (1952). Taxa in the checklist are arranged according to Smith (1950). Those forms representing new records for the state of Illinois are preceded by an asterisk.

CHLOROPHYCEAE

Volvocales

Eudorina elegans Ehrenberg. Lake Storey, Knox Co., October 13, 1963.

Tetrasporales

Sphaerocystis schroeteri Chodat. Green Oaks, Knox Co., November 13, 1963.

Gloeocystis planctonica (West & G. S. West) Lemmermann. Lake Storey, Knox Co., October 27, 1963.

Tetraspora gelatinosa (Vaucher) Desvaux. Lake Storey, Knox Co., October 13, 1963.

Oedogoniales

Oedogonium echinospermum A. Braun. Lake Storey, Knox Co., November 24, 1963.

Oedogonium gracilius (Wittrock) Tiffany. Lake Storey, Knox Co., November 24, 1963.

Oedogonium grande Kuetzing. Lake Storey, Knox Co., November 24, 1963.

Cladophorales

Cladophora crispata (Roth) Kuetzing. Lake Storey, Knox Co., October 13, 1963.

Chlorococcales

Pediastrum boryanum (Turpin) Meneghini. Lake Storey, Knox Co., November 24, 1963.

Hydrodictyon reticulatum (Linnaeus) Lagerheim. Lake Storey, Knox Co., October 13, 1963.

Ankistrodesmus falcatus (Corda) Ralfs. Green Oaks, Knox Co., November 13, 1963.

**Ankistrodesmus falcatus* (Corda) Ralfs var. *mirabilis* (West & West) G. S. West. Green Oaks, Knox Co., October 2, 1963.

Closteriopsis longissima Lemmermann. Green Oaks, Knox Co., March 3, 1963.

Scenedesmus bijuga (Turpin) Lagerheim. Lake Storey, Knox Co., November 24, 1963.
Scenedesmus bijuga (Turpin) Lagerheim var. *alternans* (Reinsch) Borge. Lake Storey, Knox Co., November 24, 1963.
Scenedesmus dimorphus (Turpin) Kuetzing. Lake Storey, Knox Co., November 24, 1963.
Scenedesmus obliquus (Turpin) Kuetzing. Lake Storey, Knox Co., November 24, 1963.

Zygnematales

Zygogonium ericetorum Kuetzing. Lake Storey, Knox Co., October 13, 1963.
Spirogyra inflata (Vaucher) Rabenhorst. Lake Storey, Knox Co., November 10, 1963.
Closterium acerosum (Schrank) Ehrenberg. Lake Storey, Knox Co., October 13, 1963.
Closterium acerosum (Schrank) Ehrenberg var. *elongatum* Brebisson. Lake Storey, Knox Co., October 27, 1963.
Closterium acutum (Lyngbye) Brebisson. Green Oaks, Knox Co., November 13, 1963.
Closterium braunii Reinsch. Lake Storey, Knox Co., October 27, 1963.
Closterium didymotocum Ralfs. Lake Storey, Knox Co., October 27, 1963.
Closterium ehrenbergii Meneghini. Lake Storey, Knox Co., October 13, 1963.
Closterium gracile Brebisson var. *elongatum* West & G. S. West. Green Oaks, Knox Co., November 13, 1963.
Closterium intermedium Ralfs. Lake Storey, Knox Co., October 27, 1963.
Closterium lanceolatum Kuetzing. Lake Storey, Knox Co., October 13, 1963.
Closterium leibleinii Kuetzing. Lake Storey, Knox Co., October 27, 1963.
Closterium lunula (Mueller) Nitzsch. Lake Storey, Knox Co., October 13, 1963.
Closterium moniliferum (Bory) Ehrenberg. Green Oaks, Knox Co., November 13, 1963.
Closterium parvulum Naegeli. Green Oaks, Knox Co., November 13, 1963.
Closterium strigosum Brebisson. Green Oaks, Knox Co., November 20, 1963.
Closterium turgidum Ehrenberg. Lake Storey, Knox Co., October 27, 1963.
Cosmarium circulare Reinsch. Lake Storey, Knox Co., November 24, 1963.
Cosmarium cucumis (Corda) Ralfs. Lake Storey, Knox Co., November 24, 1963.
Cosmarium formosulum Hoffman var. *nathorstii* (Boldt) West & G. S. West. Lake Storey, Knox Co., November 24, 1963.
Cosmarium speciosum Lundell. Lake Storey, Knox Co., November 24, 1963.

EUGLENOPHYCEAE

Euglena acus Ehrenberg. Lake Storey, Knox Co., November 10, 1963.
Euglena acutissima Lemmermann. Lake Storey, Knox Co., October 27, 1963.
Euglena deses Ehrenberg. Lake Storey, Knox Co., October 27, 1963.
Euglena elongata Schewiakoff. Lake Storey, Knox Co., October 27, 1963.
Euglena gracilis Klebs. Lake Storey, Knox Co., October 27, 1963.
Euglena oblonga Schmitz. Lake Storey, Knox Co., October 27, 1963.
Euglena oxyuris Schmarda. Lake Storey, Knox Co., October 27, 1963.
Euglena spirogyra Ehrenberg. Lake Storey, Knox Co., October 27, 1963.
Euglena spiroides Lemmermann. Lake Storey, Knox Co., November 10, 1963.
Euglena tripteris (Dujardin) Klebs. Lake Storey, Knox Co., October 27, 1963.
Phacus acuminatus Stokes. Lake Storey, Knox Co., October 13, 1963.
Phacus pleuronectes (Mueller) Dujardin. Lake Storey, Knox Co., November 10, 1963.
Trachelomonas armata (Ehrenberg) Stein. Lake Storey, Knox Co., November 10, 1963.
Trachelomonas hispida (Perty) Stein. Lake Storey, Knox Co., November 10, 1963.
Trachelomonas volvocina Ehrenberg. Lake Storey, Knox Co., November 10, 1963.

XANTHOPHYCEAE

Tribonema minus (Wille) Hazen. Green Oaks, Knox Co., November 13, 1963.

CHRYSOPHYCEAE

Dinobryon divergens Imhof. Green Oaks, Knox Co., April 9, 1963.

DINOPHYCEAE

Glenodinium palustre (Lemmermann) Schiller. Lake Storey, Knox Co., October 27, 1963.
Ceratium hirundinella (Mueller) Schrank. Green Oaks, Knox Co., April 13, 1963.

MYXOPHYCEAE

Polycystis aeruginosa Kuetzing. Lake Storey, Knox Co., November 10, 1963.
Anacystis peniocystis (Kuetzing) Drouet & Daily. Lake Storey, Knox Co., November 10, 1963.
Merismopedia convoluta Brebisson. Lake Storey, Knox Co., October 27, 1963.
Coelosphaerium collinsii Drouet & Daily. Lake Storey, Knox Co., November 24, 1963.
Oscillatoria chalybea Mertens. Lake Storey, Knox Co., November 10, 1963.
Oscillatoria curviceps C. A. Agardh. Lake Storey, Knox Co., November 10, 1963.
Oscillatoria geminata Meneghini. Lake Storey, Knox Co., October 27, 1963.
Oscillatoria grunowiana Gomont var. *articulata* (Gardner) Drouet. Lake Storey, Knox Co., November 10, 1963.
Oscillatoria tenuis C. A. Agardh. Lake Storey, Knox Co., November 10, 1963.
Lyngbya aestuarii (Mertens) Liebmann. Lake Storey, Knox Co., November 24, 1963.
Lyngbya birgei G. M. Smith. Green Oaks, Knox Co., October 2, 1963.
Aphanizomenon flosaquae (Linnaeus) Ralfs. Green Oaks, Knox Co., October 2, 1963.

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EFFECTS OF DEER BROWSING ON SOYBEAN PLANTS, CRAB ORCHARD NATIONAL WILDLIFE REFUGE

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ABSTRACT. — Randomly selected soybean plants were marked to establish utilization by white-tailed deer. Seventy-four percent of the tagged plants were browsed at least once during the growing season. The reduction in the production of seed of clipped plants averaged 48 percent per plant; the total damage to the soybean crop was 39 percent. Solutions to the problem include reduction of the deer population and/or application of repellents to field borders.

Since the establishment of the Crab Orchard National Wildlife Refuge, the United States Bureau of Sport Fisheries and Wildlife has developed an intensified agricultural program to provide fall and winter foods for wintering Canada geese. Concurrent with the development of this area as a winter home for geese the population of white-tailed deer has increased rapidly. Farmers, who lease lands in the refuge for intertilled cropping, make repeated claims that deer cause extensive damage to crops, especially soybeans which represent one of the two (corn) most important cash crops on the Crab Orchard National Wildlife Refuge. The increasing deer herd prompted an investigation of the deer population in relationship to the habitats afforded by the refuge. This paper reports a study of deer depredation on soybeans. Appreciation is expressed to refuge personnel and leasee farmers for cooperation which made this study possible.

TECHNIQUES

Five fields dispersed throughout the refuge were used as a basis for determining the extent of deer utilization of row-planted soybeans. These fields encompassed 42 acres and ranged in size from 6.5 to 11.0 acres. Two of the fields were situated in bottomland and the remainder in upland.

A browse survey was used to determine the extent and nature of the clipping. Nine hundred and forty-one soybean plants were tagged during June

TABLE 1.—Number of Clipped and Unclipped Soybean Plants and Seed Production, Crab Orchard National Wildlife Refuge, 1964.

Field	Number of Plants and Weight of Seeds (gm)							
	Clipped Before Plants Tagged		Clipped Between First and Second Check		Clipped Twice Prior to Both Checks		Not Clipped	
	Number of plants	Average weight	Number of plants	Average weight	Number of plants	Average weight	Number of plants	Average weight
1	51	3.9	16	3.3	10	3.0	34	5.7
2	56	6.5	19	8.7	38	7.4	57	9.7
3	15	6.2	6	8.1	6	6.0	30	6.2
4	26	1.9	2	1.9	10	1.2	19	3.3
5	116	2.2	27	1.5	191	1.1	10	2.1
Total	264	3.6	70	4.4	255	2.3	150	6.5

and early July, 1963. A three-inch piece of yellow and red plastic, engineers' tape was stapled around each plant just above the cotyledons; this prevented the tags from being covered by cultivation and enabled easy identification. It is not believed that the tags affected selectivity of plants for browsing by deer. Plants were tagged in groups of 1-3 at intervals of 30 paces; every 20th row across each field was tagged in this manner.

Marked plants were checked for early and late-season clipping. The early survey was made when the plant was approximately 5-6 inches above the ground. The check for late clipping was made prior to the soybean harvest. When the soybeans were mature (September) each tagged plant was harvested and the seeds dried and weighed to determine the difference in production of clipped and unclipped plants. A total of 739 tagged plants were available for these analyses; 202 plants were lost due to various causes but largely as the result of ground hog activities.

The advantages of this browse survey method are expediency and lack of expense. Plastic markers are inexpensive and may be quickly fastened by utilizing a stapler; whereas, exclosures are expensive and time consuming to erect and locate. In addition, tagged plants need not be tended and may be cultivated concurrently with the rest of the field.

Results and Analysis

The average weight of seeds from unclipped soybean plants (6.5 gm/plant) was almost double (Table 1) that of plants clipped early in their growth (3.6 gm/plant). Plants which were clipped prior to the initial check suffered more than plants which were clipped when the plants were more mature (4.4 gm/plant). Plants recorded as browsed at both times when checked produced the least amount of seed (2.3 gm/plant).

Individual fields varied considerably from the average. For example, in Field #3, the average production of plants clipped prior to either of the checks was higher than the average for unclipped plants (Table 1). Weeds were the cause of this deviation; in some areas, pigweed, horseweed, and jimpsonweed shielded the plants from browsing by deer. However, these soybean plants were long, slender and yielded few productive pods. These data indicate that a serious weed problem may be more harmful to the soybean crop than deer browsing.

Deer beds were common in grass-infested areas of fields; two areas approximately 25 feet in diameter had been used so heavily that the surface soil was dusty. Actual damage resulting from trampling by deer was limited. Observations of tracks revealed that the deer usually followed the rows and dead furrows while feeding.

Browsing by deer was heaviest during the first 3 weeks of soybean growth; the plants were probably more palatable at this time. However, the size of the plant may have been important. Larger plants had more leaves; this possibly reduced the number of individual plants on which deer fed.

Early clipping usually involved the loss of the terminal bud. The plant responded by developing two lateral shoots which were inferior in seed production to the main stalk of a normal plant. Later in the season, only a leaf or two was eaten, which was not as critical to subsequent plant growth and production.

The data obtained from this investigation indicates that white-tailed deer are a serious threat to the soybean crop and thus to the income of the farmers. Seventy-four percent of the marked plants were clipped at least once during the summer. Seeds from these plants averaged 3.1 grams/plant compared to 6.5 grams/unharmed plant. The results of this study revealed that the total soybean crop production was reduced 39 percent by feeding activities of deer.

The most obvious solution to the problem of deer depredation would be partial removal of the deer herd. The application of deer repellents may also be considered. Chemicals such as Goodrite Z.I.P. and Diamond-L could be applied along edges of fields when the plants were 2 to 3 inches in height; field edges were most severely damaged by feeding deer. The effect of deer browsing was found to be 25 percent greater in the outer 20 rows than for the remainder of a field. Observations revealed that deer began feeding along the edge and then moved toward the center. If the outer rows were treated with a repellent, the deer might leave without browsing. Provided these chemicals were effective, this method would allow the soybean plants to pass through the initial critical period of growth. Subsequent applications could be applied as necessary.

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VASCULAR CAMBIAL INITIALS IN EASTERN COTTONWOOD IN RELATION TO MATURE WOOD CELLS DERIVED FROM THEM

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ABSTRACT.—Lengths of fusiform cambial initials of eastern cottonwood show variations depending upon their position with respect to side and amount of lean of trunk. Their average lengths increase with increase in lean on both upper and lower sides of the tree trunk. In relation to side of trunk, both vessel cell and fiber lengths increase with lean; within the trees the vessel cells are greater in length on the upper side of lean, whereas the fibers are longer on the upper side in moderate lean but in severe lean their lengths become considerably greater on the lower side of lean.

This study was undertaken to determine the relationship between cambial initial length and mature wood fiber and vessel cell lengths in nearly vertical and severely leaning trees of eastern cottonwood (*Populus deltoides* Marsh.). Fiber-length variations are known to occur in this species (Kaeiser, 1956), and the lengths of these cells are greater on the lower side, in trees with severe lean from the vertical, than in cells on the upper side of the trunks. Bailey (1920) has reported that the cambial initial lengths in an unidentified species of *Populus* are only slightly less than in the mature vessel segment (cell), whereas the averages for fiber cells were almost twice that length. No record was given for leaning trees.

MATERIALS AND METHODS

In April of 1962 two young (10-11 year old) trees growing by a temporarily abandoned stream bank on Southern Illinois University campus were felled. One tree had a 3-4 degree lean from vertical, and the other more than a 12 degree lean from vertical at 4½ feet above ground level. Measurements of lean were made with a plumb bob device made for the author at the U. S. Forest Products Laboratory. Complete discs about one-half inch thick were sawed from each trunk after labelling upper and lower sides of leans of trunks. The discs were wrapped in plastic and refrigerated until the outer sections of the discs could be cut. An electric hand saw was used in the laboratory to remove three outer contiguous sections of the discs in the region of upper and lower sides of each disc, enough to include the outermost three rings of wood. The sections were sawed to include approximately three-fourths inch of cambium. The outer bark was cut off with a razor blade, leaving the inner bark, the cambium and the outermost three rings of wood. Slices approximately 10 microns in thickness were cut from these portions of the discs, after the samples had been strapped on the holder of a Super Histo-Freeze with a gum mastic solution and frozen for at least 20 minutes. The slices for observation were taken in such manner as to show precisely tangential views of the cambial initials, the vessel cells and the fibers. Parenchyma of the rays was not used in this study, nor was the phloem. Approximately a dozen slices were selected from among some 25-50 preparations for the measurements made on cell lengths. The slices were killed and fixed in the usual manner with FAA and were prepared with the tannic acid-iron chloride stain. All measurements were made from camera lucida projections. Averages of 25-30 cambial initial lengths were obtained. Because of their fusiform shape, care was taken to include measurements only of those cells showing the typical fusiform appearance.

After the slices were procured, the rings of wood were removed from the portion of each section remaining, cut lengthwise along the grain of wood into match-stick size and macerated in the usual manner with Jeffrey's solution. The macerated wood, after washing, was tinted slightly with Safranin O and stored in 70% ethyl alcohol. From a suspended mixture of each macerated sample a random sample was removed with a tube of 4 mm bore, placed on a clean dry microscope slide and covered with an oversize coverglass. The first 100 whole fibers and vessel cells were measured, as indicated in Table 1.

TABLE 1.—Lengths of Fusiform Initials, Vessel Cells and Fibers from Areas of Upper and Lower Sides of 10-11 Year Old Eastern Cottonwood Trees With 3-4 Degree and Greater Than 12 Degree Lean. Sampled at 4½′ From Ground in Two Trees in April, 1962. Vessels Cells and Fibers were Measured From Macerations of Outer 3 Combined Rings (9th-11th Rings) From Pith.

Side of Lean	Average Length of		Cell Lengths from Tree of: 3-4° Lean	Greater Than 12° Lean
Upper	Fusiform Initials from Tangential Sections		0.556 mm.	0.659 mm.
	1st 100 Whole Vessel Cells	Total length	0.598	0.669
		Mid-Perforation length	0.405	0.453
	1st 100 Whole Fibers		0.865	0.883
Lower	Fusiform Initials from Tangential Sections		0.521	0.609
	1st 100 Whole Vessel Cells	Total length	0.563	0.658
		Mid-Perforation length	0.394	0.450
	1st 100 Whole Fibers		0.783	0.955

RESULTS AND DISCUSSION

The upper side of leaning tree trunks of angiosperms contains the reaction or tension wood. The figures assembled in Table 1 show that in a tree with severe lean the fibers tend to be longer on the lower side. This agrees with previous findings by the author (Kaeiser, 1956). In the tree with greater than 12 degree lean the fusiform cambial initials were longer, on the average, on both its upper and lower sides than in the tree with 3-4 degree lean. However, both trees had longer fusiform initials on their upper sides. This suggests that the further elongation of fibers on the lower sides of trunks with severe lean would be independent of cambial initial lengths.

Total lengths of vessel cells are greater, on both sides, in the tree with severe lean. Within each tree the average increase in total length of vessel cells when compared to average lengths of fusiform initials, was the same on both sides in tree of slight lean (0.042mm); in the tree with severe lean the vessel cell lengths increased over fusiform initial lengths more on the lower side. However, in the tree with severe lean, the cambial initials were shorter, on the average, on the lower than on the upper side, and the vessel cells also were of shorter average length on the lower side. This is the reverse of the observations made of the fibers.

Extension of the study to include samples from trees derived from a single clone growing under different mineral conditions, and also samples taken during different periods of the growing season, is now under way.

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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 and one carbon copy should be submitted.

Titles should be brief and informative. The address or institutional connection of the author appears just below the author's name. An abstract must accompany each article. Subtitles or center headings should be used; ordinarily one uses subtitles such as *Materials*, *Methods*, *Results*, *Discussion*, *Summary*, *Acknowledgments*, and *Literature Cited*.

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ANSWERS TO QUESTIONS: PANEL DISCUSSION, FIFTY-SEVENTH ANNUAL MEETING

Editor's note: President Elnore Stoldt asked four Past-Presidents of the Illinois Academy of Science to answer, at the 57th Annual Meeting, the questions posed in the presidential addresses that each gave at the end of their tenure in office.

THE IMPORTANCE OF BEING NOURISHED A REVIEW AFTER FIVE YEARS

HARLOW B. MILLS
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It was scarcely daylight when we arrived at the airport in Belém, Brazil. This is a relaxed area; the plane's crew didn't arrive until twenty minutes after departure time, but soon we were airborne and heading northwesterly across the south arm of the Amazon, across the tremendous estuarial island of Marajó, across the north arm, and in something over an hour we were descending toward the city of Macapá, the capital of the Territory of Amapá. Here we were whisked off to the interior of the Territory in the general direction of French Guiana. As we left Santana in a flange-wheel bus, we crossed the equator the third time that morning; once coming in the plane, once in the car taking us from Macapá to Santana, and once in the bus leaving Santana.

We were heading into the fetid tropical jungle, with all of its dangers and ills. But the jungle had to wait while we traversed 100 kilometers of tropical savanna to Porto Platon and the Amaparí River. At this point we encountered the dense growth one associates with the tropics where rainfall is abundant and temperature high, and we were in it all the way to Serra do Navio, the other railhead, where the mine was located.

Cut right out of this jungle growth was a modern city of about 2,000 people. The ambitious forest pressed in on the clearing on all sides. We were settled in delightful guest quarters with screened windows, fans and even refrigerators stocked with cold drinks. Then we were taken on a tour of the city. We saw the recreation hall and its swimming pool, the theater where movies are shown, the school, the super market, the laundry, the bakery, and the ice plant. As we drove on to the hospital there were toucans yelping in the jungle on our right.

The hospital had been saved for the last, for it was their jewel, the showplace of the city. It was immaculate and comfortable. It had an out-patient clinic, doctors in numerous specialities, and 36 beds. It had an operating room and modern X-ray equipment, and all meals were planned by professional dietitians.

I talked to Dr. Paulo Antunes, the health adviser for the mining company. What were the greatest causes of hospitalization, I wondered. Did malaria give them much trouble? How about yellow fever, filariasis, schistosomiasis, Chagas disease?

Dr. Antunes smiled and said, "Our greatest cause for hospitalization is childbirth. We have these other things licked."

I have been asked to enlarge on the presidential address I gave before the Academy in 1959, and to point out areas where we have made some progress. Unfortunately, I cannot do the latter, for we have made little discernible progress in this important matter of numbers of people. The world population is growing at the rate of 5,600 souls an hour, and even the *rate* increases a little with each hour that passes.

Much has been said about this paramount problem since the talk I gave in 1959. More people are interested. High level agencies have pontificated on the subject. Each one seems to be striving to say the same things in a different way, to impress a public that remains stolidly unimpressed. Man seems to be able to manage everything but himself.

To get to the matter of food, or the lack of it, appetite is an individual thing. We each have one. But there are more of them all of the time in this finite world. For the moment let us narrow our view to the United States alone.

Right now there are about 180,000,000 people in the country. There were at the last count about 1,124,000,000 acres of agricultural land. Simple arithmetic indicates that this gives each person 6.24 acres for his support. Demographers believe that the population will double in 40 years to an estimated 360,000,000 people. Agricultural statistics show that this agricultural land is being usurped for non-agricultural uses at the rate of over a million acres a year. If these figures are somewhere near correct, and if the trends continue, about the year 2,000 we will have 360,000,000 people and 1,084,000,000 acres, and the average agricultural acreage for each person will have dropped from 6.24 to 3.0.

If this occurs, our food production from each acre of land must more than double; we will have to be 108% *more* efficient than now. When one considers that the introduction of hybrid corn increased our corn production by a third, and this over a period of 25 years according to Director James G. Horsfall of the Connecticut Agricultural Experiment Station, one can see what the magnitude of the task in the next 40 years is.

If we assume that the calculations are 50% in error we still have a job the magnitude of which is astounding. And we are the best fed country in the world. In less fortunate areas things do not get better. For example, in Brazil, where production increased in 1963 by 2.4% the population increased by 3.1%. We read that in Mexico the birth: death ratio is 4:1 and that in 20 years there will not be 36 million Mexicans, there will be 70 millions. Can these people be fed an adequate diet? In Ceylon the death rate has dropped from 21 to 12 per thousand, the population increased 30% from 1950 to 1960; the per capita income at $129 in 1955, a bare subsistence level, dropped 10%. James A. Michener says that the population of Asia will increase from 1.5 billion to 3.5 billions during the lives of many now living. Further, he says that in countries like India a third of the people now exist on 20c a day. These people are hungry people. The National Academy of Science says that it took the first 1,700 years after Christ to double the world's population, it doubled again in the next two centuries, again in less than 100 years, and the present rate of production will telescope the phenomenon of the first 1,700 years into 35 years.

This is not an even growth. Japan and most European countries will double in 50 to 100 years; the Soviet Union, the United States, Australia, New Zeland, Canada, and Argentina are a little faster, doubling in 30 to 40 years; the great underdeveloped, already hungry areas including most of Asia, the Philippines, Indonesia, Africa, Caribbean Islands, and most of Latin America will double in 20 to 40 years.

We hear much of the balance of nature these days. The balance of nature can be defined as a state where every species in the environment is at harmony with every other one, in that each makes no demand on the environment greater than its contribution. This is really an unattainable situation, and it can be approached only whereon one component does not set up standards which favor itself over the other components. Man has set up just such standards for himself and, what is more, has built in certain feed-back mechanisms which further enhance his position. There is woefully little any more that comes close to a balance, but I shall leave to Dr. Evers (with my very strong endorsement) the task of enlarging on the subject of our needs for preservation of natural areas.

I am not really disturbed but that nature will take care of this human upstart in one way or another. Man never seems to have enough time, but time is what nature has the most of. What I am disturbed about is *how* this equalization will take place. As reasoning beings, we have a chance to fit ourselves into the environment—or we did have such a chance one time—and to continue in reasonable harmony, making our demands and contributions to this environment balance. But this we are not willing to do, and in the course of time nature will step in.

The President of the National Academy of Science has this to say, "The problem of uncontrolled population growth emerges as one of the most critical issues of our time since it influences the welfare and happiness of all the world's citizens. It commands the attention of every nation and society . . ." I must agree with President Sietz. I must also agree with Director Horsfall when he says, "We live indeed in the fat years. May the lean continue to be something we only read about in the Old Testament."

SOME IMPLICATIONS OF SCIENCE FOR OUR SPACE AGE SOCIETY—FOUR YEARS LATER

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Four years ago it was my privilege to address this assembly concerning some implications of science for mankind in the next decades. Several questions (none original) were posed with respect to the intellectual climate, the role of science in the humane tradition, and the future direction of science. The time allotted was utilized to develop background for these questions, thereby providing a convenient escape from the responsibility of suggesting possible answers. It would be presumptuous to imply that I have discovered the answers in the intervening years. It is more likely that my appearance this morning is mere testimony to a vanity deriving from our president's invitation to participate in this panel presentation. Those who read regularly *Science,* the journal of the AAAS, are aware of the more frequent discussions of the scientific climate and the role of science in the humane tradition that have appeared in its columns within the past few months. Perhaps my function this morning might be to comment upon these two topics and recent trends of thought concerning them.

The climate of science seems neither better nor worse than four years ago. The events that create the climate have failed to match the explosion of the first atom bomb or the launching of the first sputnik in the immediate effect upon the sensibilities of the lay public. Richard Hofstadter (1963, p. 5) has noted a significant change for the better in the intellectual atmosphere since October, 1957, although he does not suggest that the vigilante mind has disappeared or that anti-intellectualism has ceased to be a force in American life. Perhaps his optimism is based too much upon the late President Kennedy's hospitable disposition toward intellectuals in public life. As Hofstadter prepared his manuscript, he was encouraged by "the new President's obvious interest in ideas and respect for intellectuals, his ceremonial gestures to make that respect manifest in affairs of state, his pleasure in the company and advice of men of intellectual power, and above all by the long, careful search for distinguished talents with which his administration began." However, Professor Hofstadter was not under the illusion that "the recruitment of such talents would altogether transform the conduct of our affairs." Perhaps it is reasonable to say that the late President set the tone for recognition of the need for intellect in the affairs of mankind, e.g. the White House dinner for the Nobel Prize winners, his interest in space research and in the National Academy of Sciences, or his respect for intellect paralleling that rendered by Thomas Jefferson, to mention but a few incidents directly related to science. One may only guess at the potentialities of the intellectual climate had Mr. Kennedy survived to complete his administration with possibly a second term of office.

There are those who say that the scientific climate is suffering in Washington, especially in view of what seems to be an increasing skepticism in Congress regarding government support for research. Inevitably a congressman unhappily discovers and misinterprets the title of a research project, thereby furnishing colorful news copy that strikes a response among anti-intellectuals and those who fear or ignore science. Senator Anderson (1964) suggests "a growing uneasiness in Congress about its own ability to oversee programs effectively." He mentions the "cost consciousness" of Congress, i.e. its concern for the relationship of cost to performance in the area of research and development. D. S. Greenberg (1964) reminds us that "Congress did not reduce federal support for research. It did reduce the rate of growth that had prevailed in recent years." Even the National Science Foundation had its budget increased $31 million although it had hoped for an increase of $267 million. Greenberg speaks of the "icy reception" of the proposed budget in the House of Representatives and the resulting "lecture on the perils of rapid growth." The National Institute of Health sought and obtained an increase of $38 million, an increase somewhat smaller than in previous years. But Greenberg also notes the enormous increase in the share of the budget designated for research and development. He cites congressional support of research in high-energy physics and oceanography, and passage of the college-aid bill as indications that Congress is not hostile to science. He does not regard the investigations and studies by various congressional committees as indicative of ill treatment of science, but rather as desirable discussions of long-standing problems arising from the complexities inherent in the more significant aspects of research.

Threats to the intellectual climate are not entirely outside the realm of science. Readers of *Science* are aware of the current debate as to whether evidence from science may bear upon the race problem. Persons of academic distinction have published assertions that scientific evidence proves the members of Negro races inherently less competent than individuals of other races. Data are cited to justify inequities in civil rights and to challenge the Supreme Court's decision of 1954 on school segregation. The report of the AAAS Committee on Science in the Promotion of Human Welfare (1963) makes clear that "the issues concern not only the validity of allegedly scientific conclusions but also fundamental principles that affect the integrity of science." These allegations are scarcely new. Your speaker heard them voiced at various times by persons of academic attainment during his years of study.

There is not time this morning to summarize the arguments of those who contend that scientific evidence demonstrates significant inequalities between the Negro and other races, nor to summarize the report by the Committee on Science in the Promotion of Human Welfare. For the most part the debate among scientists has been conducted on a fairly high level of discussion, at least in the columns of *Science*. It is essential, however, that we recall parallel situations in other times and places, notably between 1933 and 1944 in Nazi Germany and in the past three decades in the Soviet Union. Merely to mention the prostitution of science to serve the ends of the Nazi dogma of race purity or the attack upon genetics in Russia should be sufficient to remind us that, as Robert Merton (1957) puts it, when "such doctrines percolate to the laity, they invite a general distrust of science and a depreciation of the prestige of the scientist, whose discoveries appear arbitrary and fickle." The scientist may soon be caught with a variety of anti-intellectualism on the ideological front which entails a conflict with the traditional assumption of the objectivity of modern science. The recent research by Robert Rosenthal on the bias of the experimenter, a topic viewed with trepidation by some psychologists, may ultimately serve to question the available evidence on the measurable differences among racial groups and to underscore the possibility that we can prove whatsoever we set out to prove.

One of the most significant factors in the climate of science in the past five years derives from two lectures delivered in 1959 and 1960 by the former physicist and present man of letters, C. P. Snow. The first lecture, delivered at Cambridge University and entitled *The Two Cultures and the Scientific Revolution* (1959) (and recently, *The Two Cultures: and A Second Look* (1963)), has had enormous influence in focusing upon the demise of a common culture and the existence in virtual isolation of two groups more or less hostile toward one another, between whom there is little or no communication—the scientists on one hand and the practitioners of the humanities, constituting the non-scientific viewpoint, on the other. Snow argues that the scientific revolution has greatly improved social conditions by decreasing poverty, hunger and disease, i.e. closing the gap between the privileged rich and the unfortunate poor at opposite ends of the socio-econonmic scale. Snow indicts the humanists of the 19th and 20th centuries for antagonism to the scientific revolution which he holds primarily responsible for social change.

Snow's second lecture, delivered at Harvard University under the title of *Science and Government* (1960), contains the argument that scientists should participate more widely in government because of the attitude and habits of thought peculiar to the scientific mind, particularly the quality of foresight possessed by many, but not all scientists. This virtue the scientist can bring to the conduct of public affairs, especially in the realm of decision-making by administrators who tend to avoid the free debate of legislators and the free discussion of scientists and who deal with short-term solutions. Snow observes that the Western world must change to survive the challenge of the communist world, but that it is unable to change because there is no model for the future. As Moody Prior (1962) analyzes Snow's essay, the communist countries are "convinced that the future is theirs and are sure that they know its form because they are confident of their ability to shape it." Snow holds that Western society must likewise become "future-directed," and that those best prepared by habit and traits of character to develop such a society are the scientists. Snow cites that which to him is a horrible example illustrative of the precept that no one scientist should exercise unlimited influence.

The humanists were not slow to answer Snow's arguments. F. R. Leavis, the British literary critic, has attacked the materialistic implications of Snow's view that improved social conditions stem from the scientific revolution (Margolis, 1962). However Leavis does not tend to deny the desirability of better communication between nonscientists and scientists. Robert Hutchins (1963) repudiates Snow's views on scientists in the government and holds that there is but a single culture, the pseudo-scientific. Jacques Barzun (1964) adopts a confusing position summarized by George Gaylord Simpson (1964): The two cultures are isolated because science lacks an equivalent of the criticism characteristic of the humanistic culture; there is a single culture—scientific; and each of the two cultures "is too diverse to count as only one."

The late Aldous Huxley (1963) takes the middle road and attacks the problem of how to make the best of both cultures, with science examining external experiences and the humanities the inner experiences of the same world. Huxley makes the case that the humanists would do well to examine the functions, psychology and language of science, and even the metaphysical and ethical problems lifted by contemporary science, that these materials might be incorporated into contemporary literature to enrich the subject matter, the expression and the vision of the total human experience. Huxley may be on the right road, for underlying the whole of the scientific enterprise is the search for unifying principles, e.g. the concept of the universe, the nature of matter, the nature of life, organic evolution, et cetera. The humanist likewise searches for unifying principles that are the basis of the total human experience, external and internal, cultural and individual.

I am convinced of Snow's thesis respecting the cultures, but I am reluctant to accept Snow's estimate of the extraordinary vision of the practicing scientist. But whether one agrees with Snow's views, his effect has been enormous in causing thinking men in all sectors of the intellectual universe to contemplate that which each culture can contribute to the other when communication between the two is improved. That is Mr. Huxley's approach to the subject. Snow and others have laid emphasis upon the humane dimensions of science in a sense opposed to those who would require the practicing scientist to foresee the consequences of his discoveries and assume personal moral responsibility for them. The Harvard report on *General Education in a Free Society* (1945) held that the humane tradition is essential for both humanists and scientists, i.e.

that all men, notwithstanding their individual specializations, should be obliged "to think effectively, to communicate thought, to make relevant judgments, to discriminate among values." A colleague of mine puts it that the goal of the humane tradition is "not simply to inform a man or excite his brilliance with brilliant footnotes. It implies commitment to seek the truth, to espouse the truth where and when he finds it, and to correct his appraisal of the truth when he finds just cause to do so. It implies commitment to seek and espouse the good and the beautiful and to correct his estimates."

Ian Barbour, a physicist who is chairman of the Department of Religion at Carleton College, has listed (1961) the issues dividing the two cultures: the irrationality of man which occupies the humanist, versus man's reason, the chief instrument of progress for the scientist; the pessimism of the humanist versus the optimism of the scientist; and the subjectivity of the humanities versus the objectivity of science. Barbour suggests that there is no inherent conflict in that each of the two cultures asks different kinds of questions, serves different functions in man's life and reflects different aspects of human experience. "The conflict arises only when either field thinks that it can replace the other and that its methods alone are significant."

That the scientific world is concerned with negotiating an understanding of the world of the humanities is indicated by the increased quantity of literature bearing upon this necessity. A single indication of the current trend is the action of the National Science Teachers Association in 1963 and 1964 to allot a significant portion of the programs of its annual convention to consideration of the humane dimension of science.

Gerard Piel, publisher of *Scientific American,* puts it bluntly (1961): "We cannot produce great scientists by stuffing little heads with chemistry and physics and mathematics. Great work in science comes out of an exposure to the whole fabric of the culture. The questions scientists are concerned with are not mean little technical issues, but important questions that concern and interest every man. They get asked only by men who have the large view and generous interests that come from literature and the arts as well as science." Piel is saying that we cannot raise scholars and scientists as means to an end, nor as instruments of national power. We educate our young people because we prize them as people while we envision the marvelous life which can be theirs if they can but realize their full capacities as human beings.

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NATURAL OR SCIENTIFIC AREAS—THREE YEARS LATER

ROBERT A. EVERS
Illinois Natural History Survey, Urbana

Three years ago I appeared before this organization and spoke on "Natural or Scientific Areas: An Illinois Resource." The conditions I described at that time were indeed dark. I wish I could stand here today and describe only bright conditions. Unfortunately, that is impossible. In some cases they are brighter than three years ago, in others they are darker. First a look at the dark side.

One of the natural areas I discussed was Grand Canyon and Chalk Bluff, possibly the largest snake den in eastern North America. Of this area I said.

> "It may be difficult to convince the public that this site should be set aside as a scientific area, because from this place the snakes of many different species spread over the countryside. Many individuals would like to kill all of the snakes. To the biologist that would be a vicious act. Our duty is to see that these animals have their niche in which to live. This place has long served that purpose and it should be protected and preserved. The area is also of archeological interest, especially the southern extremity of Chalk Bluff. How much of Illinois history lies buried there, no one knows."

Three years ago it was somewhat difficult to reach Chalk Bluff. Today it is not. A broad path, in many places constructed of crushed rock, hurries the visitor through the woods and into Little Grand Canyon. In this beautiful, narrow canyon, steps have been cut into the sandstone and the descent to the valley floor of Grand Canyon is swift and safe, that is, in dry weather. The broad path continues on to Chalk Bluff where picnic tables and restroom facilities greet the visitor. A picnic area at the most famous snake den of eastern North America! It is a mile from the parking area to the base of Chalk Bluff. I seriously doubt if many picnickers will carry their food and drink such a distance.

Unless an auto road comes into the area from the south, access is possible only by hiking or by boat on the Big Muddy River. If the picnic tables and rest facilities were placed for the benefit of boating on the Big Muddy, I would suggest that an area of this type be developed on the west side of the river, about one mile downstream, where access both by boat and automobile are possible.

In one of the tributary ravines of Grand Canyon, some digging had been done and a mass of bones, possibly Indian, remained along the path.

Will this area be protected and preserved?

Pine Hills, some distance south of Chalk Bluff, has been subjected to much "improvement". The road is being improved for better and swifter travel. Numerous parking areas have been or are being constructed. Broad paths have been built and these lead into areas that were once known only to the more adventurous person who dreaded neither greenbriers nor brambles. At Government Rock a path traverses the small hill prairie. The exotic Russian olive had been planted in the prairie but, I have heard, these have been removed. At McGee Hill, the brow slope of the bluff has been cleared of almost all of the trees and shrubbery. Crushed stone paths were constructed but apparently surface run-off was not considered as the water from the parking area is washing the crushed rock from the trail downslope toward the cliff. Let us hope no "improvements" are planned in the ravines and in the swamp.

In my address in 1961, I said:

> "Presently the University of Illinois Foundation owns land in Mason County, some of which is sand prairie and forest. The University is preserving 640 acres of this land as a scientific area. This is a great service to both scientists and laymen."

The Foundation has not yet converted this 640 acres of sand prairie and forest into a scientific area.

The lack of money is still one of the dark parts of the picture. If funds were forthcoming, many important areas could be purchased and protected. Many of us had great hopes that money would become available through an increase in the cigarette tax. The General Assembly passed legislation which would have increased this tax and a portion of it would have been used for land acquisition, including nature preserves. The act was vetoed by the Governor because of a campaign pledge he made in 1960.

It is possible for me to go on with dark side. There are, however, a few bright spots that keep me from becoming too depressed.

A few years ago one of the best scientific areas in northern Illinois was in great danger. Pressure was exerted by a group to convert the nature area of Illinois Beach State Park to a golf course. The marshes, dunes, and sand prairie of this state park are of great biological importance. We have with Beach a good example of what persons interested in preservation of irreplaceable resources can accomplish. They did not sit idly by but diligently and vigorously went to work. Because of their activities, the area concerned is still a nature area in the park. Soon, we hope, it will be officially designated as a nature preserve under supervision of the Nature Preserves Commision.

The Nature Conservancy and its Illinois Chapter have made progress. In 1961, Volo and Wauconda bogs and Rocky Branch had been or were being purchased. Presently a Sangamon River valley woods, known as Hart Woods, located near Mahomet in Champaign County, is being purchased and preserved. In northern Illinois negotiations are underway for the purchase of several valuable scientific areas. One of these is desired by an auto wrecking company as asite for "junking" old automobiles. From progress reports I have heard, such a blight on this important site will not develop.

For a number of years an area in northwestern Cook County attracted the attention of those interested in prairie. This gravel hill had been disturbed by removal of some gravel. Presently it supports a beautiful prairie. Fear was always with us that the prairie would be destroyed by more gravel removal or by use of the hill for homesites. We were especially concerned during the planning stages of the toll road. It was constructed to the north of the prairie. The Cook County Forest Preserve in its purchase of land in the vicinity included the prairie. Doubtless this valuable prairie stand will be preserved as a part of the Forest Preserve system.

You may recall that the Academy in 1961 passed a resolution favoring legislation dealing with the establishment of nature preserves. When the bill received the approval of the various legislative committees and when it passed both houses by unanimous vote, many of us had great hopes. When the Governor vetoed the bill we were very disappointed. During the last session of the General Assembly the task began again. I am happy to report that Illinois now has a Nature Preserves Commission.

The Nature Preserves Commission has nine members who are appointed by the Governor upon the advice of the Chief of the Illinois Natural History Survey and the Director of the Illinois State Museum. The Commission approves or disapproves the acquisition or disposal by the Department of Conservation of any interest in real property for purposes set forth in an act dealing with state parks and nature preserves. The Commission formulates policies for selection, acquisition, management, and protection of nature preserves and it maintains "registries and records of nature preserves and other areas of education or scientific value and of habitats for rare and endangered species of plants and animals in the State."

The legislature in the last regular session also amended the laws relative to State Parks to include nature preserves.

The Nature Preserves Commission was appointed by Governor Kerner. Their first meeting was held on January 30. At that meeting Dr. S. Charles Kendeigh and Mr. George Fell were elected chairman and secretary respectively. The second meeting of the Commission was held on March 19 and the next is to be in May. After attending the March meeting, I feel this Commission is very sincere and devoted to the acquisition and preservation of nature areas in Illinois.

Can we now lean back and rest? Absolutely not! Until we are absolutely sure that the valuable and scientific areas are secure we can never rest. Whether or not this security is accomplished depends upon the continued support of interested persons in Illinois.

THIS I WOULD LIKE TO KNOW—TWO YEARS LATER

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President Stoldt, Fellow Past Presidents, Members of the Illinois State Academy of Science, and Guests:

President Stoldt is to be congratulated on having read the addresses of four of the past presidents of the Illinois State Academy of Science. When she contacted the past presidents, Miss Stoldt mentioned that she wondered what they were doing since they were out of office. For my part, and I suspect the others can say the same, the time has been spent in doing some of the things that had been neglected. The regular duties of a regular job has kept each of us busy. During this last year I have wondered how I ever had time to attend the council meetings, answer the letters, make the plans, attend committee meetings, etc. that are required of a president. But this is not the subject that has been assigned.

"This I Would Like To Know—" was the subject of the Presidential address before this session in 1962. Several questions were asked and at that time it was thought that some could be answered in a short time. None has been answered. Some of these questions involve the fundamentals of plant science.

One question was that of, "Do auxin and auxin like compounds initiate or control the growth of cells, tissues, and organs?" Three years ago it was thought we might be close to the answer. Today we seem to be farther from the answer than we were then. In the meantime there is at least one plant scientist who insists that all is known about "auxinology" that can be known and we might as well turn our attention to some other subjects.

Some persons who were working on the initiation problems have become so involved with the problems of auxin transport that they have lost sight of the problem of "initate or control" function of auxin. Neither problem—initiation or transport—has become clearer in the last two years. Oh, yes, research has been published.

Another problem was mentioned two years ago. This was the matter of the control of cell division—either mitosis or meiosis. The question was asked, "Is there an inhibiting substances that will control the rythmn of cell division?" Is there some way to remove the inhibitor and thus speed up cell division? Of course other things must be in sufficient amount to support cell division.

This research has not progressed as rapidly as had been planned. There is the matter of purification of the organic compounds used. There had to be a separation of artifacts from a real or at least a normal response. Subtle changes in the ultra structure must be studied before an answer is proposed. This research is being carried on and there is some evidence that there may be an answer.

This is getting so it sounds like some daytime T. V. shows. They never come to a conclusion. Much research is of just this nature only there is no script.

Another question was asked—the question of differentiation. There is evidence in both the vegetative and reproductive structures that some type of determination is going on. The matter of determining which cells will produce a branch or a leaf on a vegetative shoot has been reviewed many times in many different kinds of plants. The development of reproductive organs, with both sexes involved, in one larger organ of the higher plants, has been used to discuss the differentiation of cells, tissues and organs.

In plants, we have the mechanism for unlimited growth that presents a problem in determining just where differentiation takes place. It would be very convenient to divide the activities of a multicellular plant into three stages such as: cell division, morphogenesis, and diffentiation. In many plants these three stages may be going on at the same time in the same organ or tissue. If we think one stage leads to another then we have difficulty in drawing the limits or guidelines to separate the stages.

Research is being done in the matter of differentiation and the causes of differentiation. Several well known biologists are saying that now that we have the matter of the duplication of the gene worked out it is time we got to work on differentiation.

Two things are wrong with this idea. For one thing there are still some blind spots or areas of the unknown, at least unproven, in the theories of gene duplication. It is not true that we should start on development or differentiation but rather that we should continue our work. A number of Botanists have been working with the development of cells, tissues and organs for many years.

Some of the theories, that have been advanced in the last three years of reasearch, can be summed up in the following theories or combinations of these theories. The first might be the activator theory. A second might be the inhibitor theory, and last, we might consider the covered theory.

The activator theory indicates that there is some triggering device —chemical or physical—that we set in motion a sequence of events that will finally determine the development of a cell into the initial which will become evident only in the permanent tissue.

There is some experimental evidence that the ''puff'' structure of a chromosome is the response of hormone action and a percussor of metamorphosis in animals. It is obvious that this work was done on insects. The puff structure of the chromosome is studied in the giant salivary chromosomes of insect larvae and the metamorphosis was studied in the larva-pupa development. Peter Karlson (1) has shown that there is an enzyme that controls the development of puffs on the giant chromosomes. The development from larva to pupa is seen just so many hours after the development of the puffs, and the puffs themselves will apear just so many hours after the injection of a hormone. Karlson suggests that the puffs are evidence that the DNA of the chromosome will be forming RNA. This RNA becomes the messenger RNA which activates the ribosomes in the cytoplasm which in turn will form enzymes with the proteins of the cell. This in turn becomes the activator of cellular activities including differentiation.

There are some interesting ideas expressed here. We might ask, as does Karlson, is hormone activity necessary for gene action or to initiate gene action? The genes are all present in all of the cells of a tissue, organ or individual for the development of all the different cells and tissues required. Then why do not all cells of a flower develop into the pollen mother cells or the megaspore mother cells? This hormone activation of the gene might be part of an answer. The hormone would be nessary to stimulate the DNA to produce the right RNA to produce the ribosomes to produce the right enzymes to produce microspore mother cells or megaspore mother cells. Are two hormones necessary, or are there hormones and associated vitamins, enzymes, coenzymes, or what have you, involved?

We have been using a piece of animal research to explain the initiation of the gametophyte generation of the flowering plants. This is about as remote as any thing can be but since we have gone this far suppose we take it to another step and ask if this could be applied to vegetative development as well. Could the origin of branch roots on a geranium cutting be initiated in the same manner? We know of a growth regulating substance involved here. It is the auxin-like substances.

Now we are back to the question asked in the address before this session in 1962. Does auxin initiate or regulate, or control or maintain the production of adventitious roots on apple stem cuttings? Could auxin be the hormone that will initate the production of a messenger RNA which will cause an enzyme to start the synthesis of a hormone causing the development of adventitious root? Is there an enzyme involved or can the messenger RNA cause the root initial to develop? If auxin is involved then it is more imperative than ever that we determine if there is an initiation or a regulatory function.

A second theory about morphogenesis and differentiation is the inhibitor theory. This theory would insist that since each cell has all the genes that would control all the differentiation of all the cells of the whole organism then there must be something that is inhibiting this action. The genes would be allowed to function only if the inhibitor were removed. This may appear to be a negative approach but it is an approach that warrants some investigation. Inhibitors have been seen elsewhere in plant growth. Some chemicals have been proved to be stimulators under some conditions and inhibitors under other conditions. The simplest of these conditions might be the concentration of the chemical involved. In low concentration the chemical could become a stimulator and at a slightly higher concentration would be an inhibitor and at a still higher concentration it might prove to be lethal.

In much of the auxin work the idea of inhibitor is the idea that the inhibitor inhibits the normal growth action of the auxin. If a monophenolic compound will act in such a way that auxin can not do its proper job, and if this phenol were changed to a polyphenolic compound then auxin can function in the growth process. In this case, would the monophenolic compound be an inhibitor? Is the polyphenolic compound a growth stimulator? Do we need to define our terms? Is the enzyme that breaks down the auxin an inhibitor because less growth can take place if auxin is not present?

Then we are back to the same question again, "Is auxin the chemical that initiates cell division, cell elongation, etc., or is it a regulator of cell division and cell elongation, etc." Attempts at answering these questions were reported by Kefford (2) in a report of the 5th International Conference on Plant Regulation. On the subject of the Analysis of Development he reports, "The structures of a number of classes of compound which have been proposed as regulators have been described accurately or tentatively. The impression that plant development is the result of a developing pattern of interacting fields of those regulators has been built up. But this impression is not ready to be put to the test. The design of such tests probably depends as much upon advances in the analysis of development, down to the molecular mechanism for inter—and intracellular regulation of metabolism, as on definition of primary sites of the regulators in the cell." It has been demonstrated by workers at Oak Ridge that the dominant process in development might take place in cell enlargement rather than mitosis or in the total number of cells.

Mazia (3) of California has shown two levels of control. He differentiates between induction and maintenance of cell division. Induction may be regulated by a group of enzymes. Are any of these enzymes, or the absence of an enzyme, the inhibiting factor in the induction of mitosis? It has been pointed out by several workers that the control of the activities of a cell is the result of sequential enzyme activity. If one step in the sequence were omitted then the reaction would stop there. Then we might think that the development or differentiation of a cell might be stopped at various stages in the sequence and the cell would develop to its maximum under the sequence as far as it had gone. This could bring up the question, "What is the ultimate in development or differentiation?"

Much work has been done on the reversability of sex in Flowering Plants. Flowers that should have produced the female organs have been changed into flowers producing male organs. Again it might be assumed that there is a sequential arrangement of enzymes that will control this development and in turn there must be a sequential arrangement of the genes of a cell to direct the production of the enzymes.

Postlthwait and Nelson (4) refer to switch points in the development of the ear of corn. By the use of certain genes the switch points could be changed. This switch could change the structure of the ear to resemble the structure of the tassel in corn. They cite work done by Heslop-Harrison which shows some such effect can be brought about by NAA. Here again we might ask if there is a hormone necessary for the expression of a gene.

Stern (2), of the University of Illinois, was prompted to warn that those who speculate on the molecular mechanisms of differentiation generally do not know of the inter—or intracellular metabolic activities going on in the cell. We need to get those who are working with plant growth regulators and those working with molecular mechanism to speak with a common language. Then we may advance our knowledge of differentiation.

The third theory was that the genes on the chromosome might be covered up by the histone layer on the outside of the chromosome. This histone layer would stop the action of the gene until such time as when the histone layer could be penetrated by the gene, then the gene, presumably be able to form the messenger RNA, could carry out the sequence of the cell functions. This theory, which was proposed some two years ago, has not received much support. It may be a modification of the first theory mentioned.

Three theories to explain differentiation of cells, tissues, and organs mean that do not know what is the state of affairs, or that there may be several ways in which determination and differentiation take place. These theories may not be all the possible theories. There may be others that will more nearly explain the observed actions of plants. It may be very foolish to expect any theory that can be applied to animal differentiation might also be applied to plant differentiation.

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WEB JOINT PATTERN OF THE CAPE NEDDICK GABBRO COMPLEX, SOUTHWESTERN MAINE

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ABSTRACT. Joints in the roughly circular gabbroic pluton of Cape Neddick, Maine, are radial and tangential and form a pattern resembling a spider web. Mafic dikes, though small and not numerous, form only a radial pattern. Both dikes and joints are considered to be related and appear to have formed in the solid pluton by a mild but sudden doming action. These conclusions corroborate Hussey's findings that the gabbroic pluton was emplaced as a series of explosive intrusions controlled by cone fracturing.

The Cape Neddick complex of York County, Maine, is an oval shaped body, about 4000 feet long, composed of gabbroic rocks. It has intruded and thermally metamorphosed the Kittery Formation (Silurian?) composed of thin beds of quartzite and phyllite.

Earlier studies of the complex include those of Wandke (1922), Haff (1939, 1941, and 1943), Woodard (1957), Gaudette and Sakrison (1959), and Eldridge (1960). The most complete study of the complex is that by Hussey (1961 and 1962) which not only covers the petrology and structure but relates the Cape Neddick complex to other basic igneous complexes in the immediate area. The following description is based largely on Hussey's investigation.

The complex is composed of gabbro, anorthositic gabbro, cortlandtitic gabbro and pegmatitic gabbro (Fig.1). Along eastern and southern margins of the complex is a belt of agglomerate composed of subangular fragments (up to 8 inches across) of basalt, felsite, porphyry, quartzite, phylite, and probably crystal tuff. The agglomerate is believed to represent an early explosive phase of the complex.

Gabbro forms the outer rock belt of the complex and is rather rapidly transitional into anorthositic gabbro nearer the center. Cortlandtitic gabbro occupies the central area and appears to form lenses or tongues in the other two rock types (Fig.1). Pegmatitic gabbro also forms lenses in the outer gabbro belt. The rock distribution in plan is typically annular and resembles that of many ring complexes of New England. As a group the rocks show various types of layering as well as igneous lamination. These planar structures strike parallel to the external and internal contacts of the complex and dip inward at an angle which generally decreases from the margin toward the center. The outer contact appears to be steep or to dip inward at a high angle.

Hussey (1962) concludes that the complex was emplaced by cone-fracturing that occurred in two distinct phases. In the first phase a steep funnel-shaped block of country rock was shoved upward during the intrusion of a dense gabbroic magma. Crystallization of this melt gave rise to mafic-rich rocks at depth and to the gabbro and anorthositic gabbro now seen in the outer part of the complex. Accumulation of crystals under gravity and later formation of interprecipitate minerals largely accounts for the layering

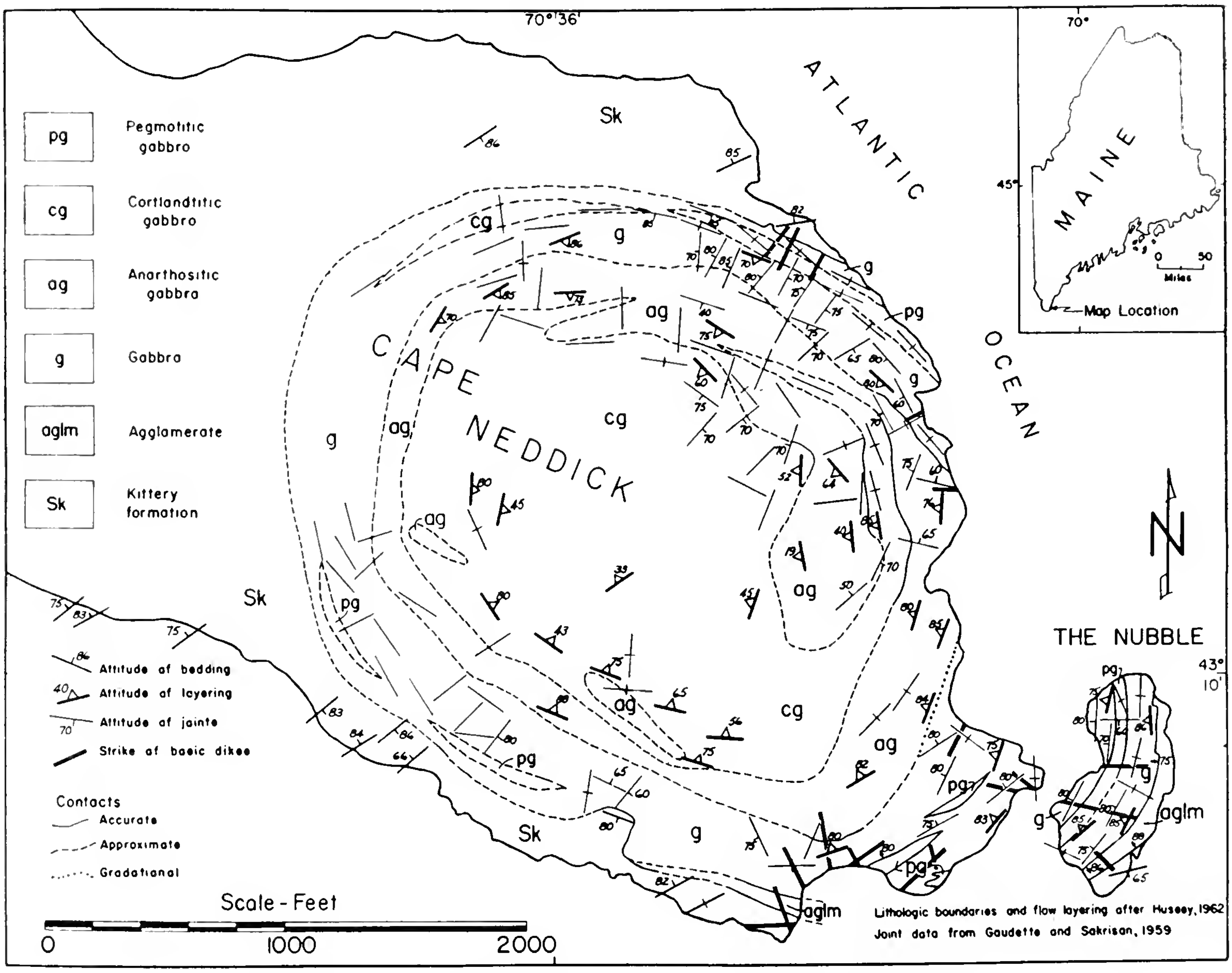

FIGURE 1.—Geologic map of Cape Neddick, Maine.

and lamination in the rocks of this first phase. Initially inward dipping planar structures may have been steepened by partial withdrawal of magma from below.

In the second phase forcefully intruded magma entered cone fractures in the gabbro and anorthositic gabbro and filled the space vacated by a funnel-shaped block near the center of the complex. Upon crystallization this magma formed the cortlandtitic gabbro. Subsequent withdrawal of magma from below may have caused steepening of layers in the cortlandtitic gabbro. Emanations associated with this second injection may have followed cone fractures and caused the earlier gabbro to be recrystallized to pegmatitic gabbro.

The sequence of rock formation was, therefore: (1) gabbro, (2) anorthositic gabbro, (3) cortlandtitic gabbro, and (4) pegmatitic gabbro.

In the light of Hussey's (1962) more recent detailed work, certain structural studies made several years earlier by Gaudette and Sakrison (1959) take on a slightly different and more significant meaning.

The structural features with which we are primarily concerned here are the joints. A plot of the joints as originally measured by Gaudette and Sakrison is shown in

Figure 1. It should be noted that nearly all readings lie within the gabbro and anorthositic gabbro phases. In spite of the fact that the central cortlandtitic gabbro is poorly exposed, it is felt that the much greater concentration of joints in the marginal phases of the complex is, in general, a correct representation.

The joint pattern as expressed in Figure 1 may be considered as constituted by two joint systems, one radial and one tangential. Two such systems in combination, if ideally developed, should give rise to a spider web pattern. In the Cape Neddick complex the web pattern appears incomplete because the central portion is so poorly developed.

Other structural features of the complex, recently investigated by the present authors but not mentioned by the earlier workers, are the few small basic dikes which cut the Cape Neddick complex. Only 18 such dikes were located, and of these all but one are less than a foot in thickness.

Microscopically the dike material appears to have been basaltic in composition. It consists of about 55% plagioclase (An_{45-65}), 15% red-brown biotite, 10% opaques, and roughly either 15% of clinopyroxene or 20-25% red-brown hornblende. The original rock textures were subophitic to intergranular. Fluidal structure with well-oriented plagioclase laths is common throughout the smaller dikes and near the contacts of the large one.

Recrystallization and alteration of the dike material appear as extensive phenomena. Locally original textures remain; but due to recrystallization, grains have become rounded and mutually embayed so the rock takes on a hornfelsic texture. Clinopyroxene is the principal primary mineral, but much has been converted to hornblende and biotite. Considerable hornblende has also been changed to biotite. Biotite is generally more abundant where the content of pyroxene plus hornblende is lower.

Closely associated with some of these basic dikes are intermediate to granitic phases and the relationship between different types may be of a simple or complex nature. The microscopic features of the dikes in this association resemble those of certain dikes at Mount Desert Island, Maine (Chapman 1962).

When plotted on the map (Fig.1) the basic dikes appear to present a radial pattern. It is possible that their restriction to the marginal portion of the pluton is more apparent than real because of the better exposures in this region, however, the radial pattern and basaltic composition suggest they are genetically related to the Cape Neddick complex. The dikes are obviously younger than the gabbro and anorthositic gabbro; but, because of their petrographic character, they are probably not related to the cortlandtitic gabbro. It seems logical, however, to consider them contemporaneous with or younger than the radial joints.

The history of development of the web joint pattern may have been rather complex. The joints are obviously all post-gabbro and post-anorthositic gabbro in age, and some at least must be post-cortlandtitic gabbro in age.

Hussey (1962, p. 48) considered that the arcuate masses of cortlandtitic gabbro in the outer part of the complex are cone sheets, which formed as the central mass of cortlandtitic gabbro was emplaced. Some of the tangential joints in the outer part of the complex may represent cone fractures, formed during this same explosive phase, which never opened sufficiently to admit the mafic magma. Had most of the tangential joints formed at this time, it would seem that cone sheets should be numerous in this area. Since radial fissures filled with cortlandtitic material have never been found here, it seems likely that the cone fractures were adequate to relieve the stress and that few if any radial joints formed at this time. Furthermore, Hussey's (1962, p. 48) conclusion that considerable recrystallization of the gabbro to form pegmatitic gabbro may have taken place along principally one cone fracture due to rising emanations, and the fact that such recrystallization is not known to have occurred along any radial joints would also indicate that few if any radial joints, had formed. It appears, therefore, that nearly all the radial joints and most of the tangential joints formed after the cortlandtitic gabbro was emplaced.

The web pattern, therefore, may be ascribed to a still later but relatively minor explosive phase. Such an impulse may have been not only less violent; but it may have occurred more as a sudden, mild doming action accompanied by the injection of only a few thin mafic dikes. A doming movement would help explain the numerous radial joints and the small, radial basic dikes. The tangential joints would represent cone fractures which did not open sufficiently to admit the new magma.

In most other areas where cone sheets have formed, there is a paucity of these fractures in the vicinity of the intrusive center. Instead the cone sheets tend to cluster in a ring-like zone a short distance from the eruptive epicenter. This characteristic of cone sheet formation may explain the small number of tangential joints in the cortlandtitic gabbro, which occupies the central portion of the complex, and the clustering of these joints in the marginal portion.

The scarcity of radial joints in the cortlandtitic gabbro may be accounted for if it is assumed that the central portion of the complex moved upward more or less as a single conical block isolated by cone fractures. Such movements would have created little or no stretching in this central region and consequently few if any radial joints in the cortlandtitic gabbro.

In summary, it may be said that the present study of joints and dikes in the Cape Neddick complex tends to corroborate Hussey's (1962) findings. The sequence of events that led to the development of the complex and the web joint pattern in its outer portion is as follows:

1. Intrusion of gabbroic melt into a funnel-shaped opening (volcanic vent).

2. Crystallization and formation of the layered gabbro and anorthositic gabbro.

3. Slumping of the crystal mush or nearly solid rock along steep

fractures to partially obliterate, to tilt, and to partly reform the layered structure (recrystallization).

4. Sudden forceful intrusion of cortlandtitic gabbro melt to form steep cone fractures in the nearly completely crystallized earlier phases. Influx of magma into some cone fractures to form cone sheets. Upward displacement of a central cone-shaped block to form the central mass of cortlandtitic gabbro. Perhaps some recrystallization of gabbro and anorthositic gabbro occurred at this time.

5. Slumping of the cortlandtitic mass and steepening of its layered structure.

6. Sudden doming action in the solid complex, during a late and minor explosive phase, produced the web pattern of radial and tangential joints and the small radial dikes of basaltic composition.

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ORIGIN OF FISSURE FILLINGS IN A PENNSYLVANIAN SHALE IN VERMILION COUNTY, ILLINOIS

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ABSTRACT. — The top 15 feet of the marine shale above the Summum (No. 4) Coal of Illinois contains vertical fissures that could not have been formed by regional jointing. Some of the fissures are filled with siderite, dolomite, and calcite in various proportions. The fissures were developed by synaeresis, and the fillings contain two additional generations of synaeresis cracks.

A Pennsylvanian shale, mottled maroon and green at the top and grading to gray below, crops out in the bed and along the valley walls of a tributary of the Vermilion River, on the northeast side of a county road in SW¼ NE¼ SW¼ sec. 14, T. 18 N., R. 11 W., in Vermilion County, Illinois. The shale is above the Summum (No. 4) Coal (J. A. Simon, personal communication, 1964) and occurs in the marine portion of the cyclothem (Weller, 1930, p. 102).

Figure 1 shows the columnar section at the above location.

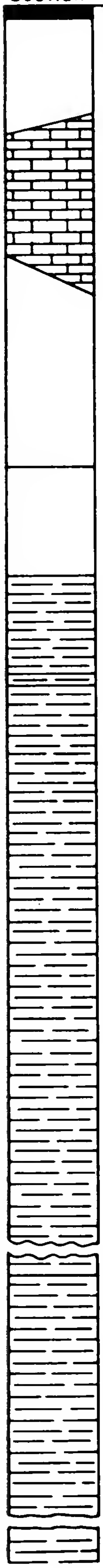
Data on the mineralogy and textural and structural characteristics of this shale are presented here, and conclusions are drawn regarding the depositional environment of the shale and the origin of its fissures and fissure fillings.

DESCRIPTION OF SEDIMENTS

The top inch of the shale is bright red, and the next 15 to 20 feet is mottled maroon and green. It contains vertical fissures that enclose polygons of noncalcareous shale. The polygons have from 3 to 6 sides and vary in size (Figs. 2-3). The outer inch of the shale bounded by the fissures is completely green, even after weathering, and outlines the polygons with green bands. The largest polygons are bounded by the widest fissures, which have calcareous, hard, greenish brown fillings. Some of the large polygons are divided into smaller polygons by smaller fissures. The fissure fillings vary vertically (Fig. 2) from a small fraction of an inch to as much as three to four inches thick. The fillings apparently become less numerous from the top of the shale down. One filling was not vertical but diagonal. The vertical fissures extend down almost to the first horizontal siderite layer.

The shale has no visible fissures below the siderite layer and is sandy near the base. The lower shale contains at least three more siderite bands below the top one. One marine fossil was found in the shale above the top horizontal siderite layer.

The clay above the shale is dark gray in the upper 18 to 24 inches and contains red stains along randomly oriented fractures. Below this lies 12 inches of light gray, sandy clay with red staining along diagonal fissures, which is underlain by 10 inches of light gray laminated shale with red and pink stains along the fissure surfaces.



Columnar Section / Description	Thickness ft.	in.
Coal	2-4	
Underclay, dark gray at top, grading into gray; slickensides	2	0
Limestone, gray, iron stained; breaks with polygonal fracture along lines of weakness; argillaceous; both surfaces uneven	2	6
Clay, gray, darker at top; iron stained along slickensides	2	0
Clay, gray, sandy; iron staining on fissures and slickensided surfaces	1	0
Shale, gray; iron-staining along fissures	0	10
Shale, red, clayey	0	1
Shale, mottled green and maroon with vertical fissures that enclose polygons of noncalcareous shale. Polygons have 3 to 6 sides and vary in size. Outer inch of shale of the polygons, which are bounded by the fissures, is green. Fissure fillings are green and brown and are composed of siderite, dolomite, and calcite	20	0
Siderite layers	0	2
Shale, laminated, greenish gray at top, grading into gray shale lower in shale section. Clayey at top, grading into sandy shale near base	25	0

FIGURE 1. — Columnar section of the rocks exposed in a series of outcrops in SW¼ NE¼ SW¼ sec. 14, T. 18 N., R. 11 W., Vermilion County, Illinois.

FIGURE 2. — Outcrop of shale with fissure fillings. Fissure fillings can be continuous for several feet (A) or may thicken and thin rapidly (B). Note hexagonal pattern.

The "fresh-water" limestone above the clay is gray, has splotches of iron staining, and its top and bottom surfaces are irregular. The limestone fractures easily along lines of weakness which form polygonal patterns.

The clay above the limestone is a normal gray to dark gray under-

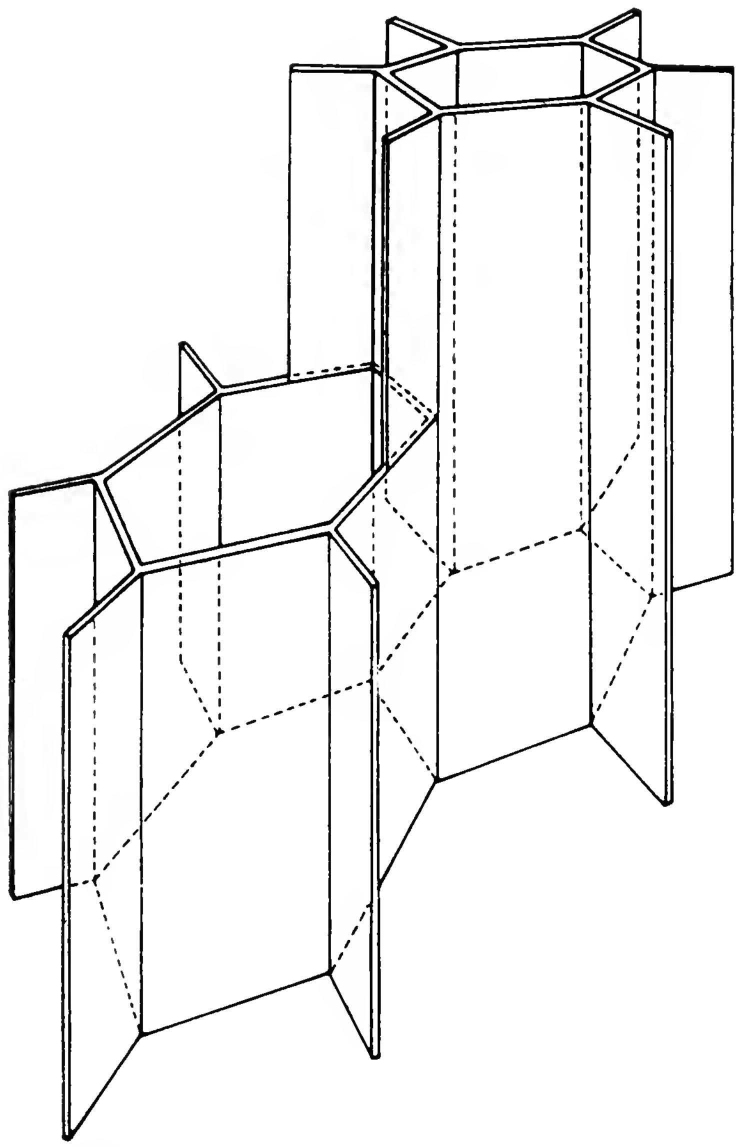


FIGURE 3.—An idealized fissure pattern for the upper 15 to 20 feet of the shale above Summum (No. 4) Coal.

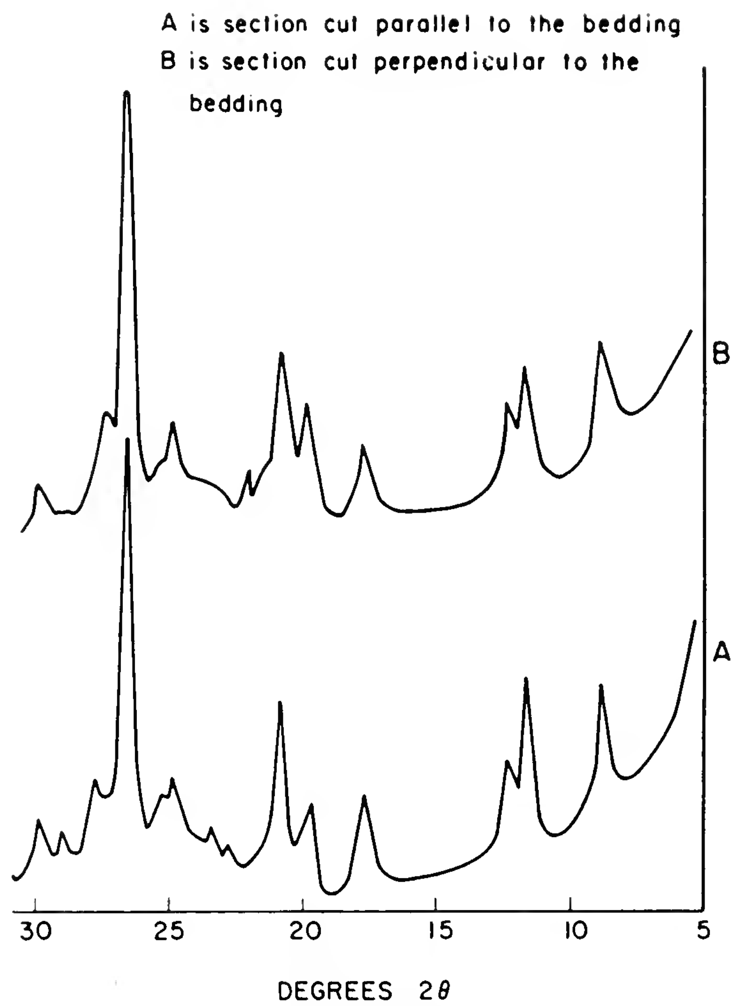


FIGURE 4.—X-ray diffractograms of the shale cut parallel (A) and perpendicular (B) to the bedding.

clay with no iron staining along the fissures.

MINERALOGY OF THE SHALE

The chief nonclay mineral in the shale is quartz. Pyrite, gypsum, and siderite also are present. The distribution of the clay minerals found in the shale is reported in Table 1.

The orientation of the clay minerals (Fig. 4) of the upper 15 to 20 feet of the shale is 0.47, which indicates a random orientation (Odom, 1963, p. 55). The equation used for determining orientation is

$$\text{Orientation} = \frac{\text{counts illite 001} \perp \text{to bedding}}{\text{counts illite 001} \perp \text{to bedding} + \text{illite 001 parallel to bedding}}$$

The shale evidently contains very little calcium carbonate, but it does have some gypsum, which is produced when sulfates formed by the weathering of pyrite or marcasite react with calcite or the exchangeable cations on the clay minerals.

TABLE 1.—Clay Mineral X-Ray Diffraction Intensities (parts in ten)

Samples	Illite	Mixed-layer	Chlorite	Kaolinite
Clay between shale and limestone	3-4	3	2	1-2
Upper 15 feet of shale	4	2	2	1
Shale below first siderite bed	4	1	3	1
Shale 40 feet below top	6	1	2	1

Description of Fissure Fillings

The fissure fillings are greenish gray but on the outside surfaces, which are uneven and contain reflecting crystal faces of calcite, they are mottled with maroon and brown. A broken or sawed surface shows a honeycomb network of veins in a greenish gray or brownish gray groundmass (Fig. 5). Close observation reveals that the veins are split lengthwise and crosswise and contain a transparent filling.

The filling in the vein was studied by both x-ray and microscope. The x-ray diffraction data showed that the filling is chiefly siderite, dolomite rich in iron, calcite, and a small percentage of quartz. The percentages of clay minerals are so low they do not show on the x-ray trace of the whole sample. When the carbonate was removed, illite, chlorite, and mixed-layer clay minerals showed up on the x-ray trace; illite made up over 50 percent of the clay minerals.

Figure 5.—Photograph of a piece of fissure filling cut and polished perpendicular to the fissure. Two generations of filled synaeresis cracks can be seen. The first is lighter than the background and the second is the darker pattern extending along and across the light fillings.

Investigation by microscope showed that the siderite and dolomite were very fine grained. The siderite had evidently formed first as a colloidal gel of very tiny crystallites with random orientation. The gel had then split into masses of various sizes and shapes, and the periphery of these masses had partially oxidized, making dark brown rims (Palache et al., 1951, p. 168) around the greenish gray siderite interiors. After the oxidation had taken place, some of the masses had been sheared by local movement. These masses are surrounded by a light yellowish brown mineral, probably the iron-rich dolomite, that transmits considerably more light than the siderite. The dolomite is fine grained, and it either has been cracked or the veins growing from each side did not quite meet. In some of the larger veins, a series of bands surround the siderite masses in the following order: an iron-rich dolomite; either calcite or a dolomite poorer in iron; iron-rich dolomite; pockets of calcite where the vein is widest; iron-rich dolomite; a layer of less-yellow dolomite or calcite; and a thin layer of high-iron dolomite adjacent to the next siderite mass. In some areas there are irregular stringers of siderite in the dolomite, indicating that the dolomite may have replaced the siderite. The dolomite veins have cross-breaks that are filled with calcite.

Table 2 gives percentages of minerals in 7 samples taken from fissure B. Fissure A is located about 100 feet from fissure B and about 2 feet higher in the shale. Table 3 gives the carbonate percentages for fissure A and the average from Table 1 for fissure B. Tables 2 and 3 show that the carbonate mineralogy can vary several per cent within a fissure and between fissures.

Table 2.—Carbonate Percentage in Seven Samples from Fissure B.

Sample	Siderite	Dolomite	Calcite
B-1	38	49	13
B-2	36	37	27
B-3	48	26	26
B-4	38	41	21
B-5	44	39	17
B-6	39	41	20
B-7	36	51	13
Range	36-48	26-51	13-27
Average	40	40	20

Table 3.—Carbonate Percentage in Fissure Filling.

Fissure	Siderite	Dolomite	Calcite
A	72	7	21
B average	40	40	20

Origin of Fissures and Cracks

Kallstenius (1963, p. 20) described two zones of fissures in Swedish postglacial clays, one seasonal and the other permanent. He stated that cracking in the first clay, which lies above the water table, occurs in the dry seasons; in the second clay, below the top of the water table, the cracking is permanent. He decided that the permanent fissures are shrinkage cracks caused by synaeresis, or chemical "drying" (1963, p. 21). His figures 41a, b, and c (1963, p. 95) show a fissured clay below a nonfissured clay in a scar left by a landslide in 1961.

Rosenqvist (1955, p. 63) and Kallstenius (1963, p. 21) suggested that the postglacial clays of the Scandinavian Peninsula were deposited in marine waters and that since uplift there has been a leaching of the sodium salts and an increase in the potassium content of the pore water. They assumed some weathering because oxidation has occurred on the fissure surfaces below the water table. Kallstenius (1963, p. 21) stated:

> The changes cause shrinkage of the clay due to decrease in michelle size and increase in strength. It should also tend to induce vertical fissures in the soil. Such effects have been observed by the present author [Kallstenius] in clay lying immediately below an area treated with lime to increase its bearing capacity.

In a fresh-water marsh, about half a mile north of Bayou Bienvenue in the Mississippi River Delta and on the east side of Louisiana Highway 47, polygonal mudcracks were developed. The polygons were about 1 foot in diameter and the fissures surrounding the cracks were from 1 to 2 inches wide. The cracks were found to extend several feet below the water table. According to Gould and Morgan (1962, p. 293), the surface of the swamp is about sea level. The water-table level was visible about a foot below the top of the cracks. That the mud had been deposited in a flocculated state was shown by the random orientation of the clay minerals in the clay (Odom, 1963, p. 79, 82). The fissures were the result of synaeresis.

Van Straaten (1954, p. 75) discussed mudcracks of subaqueous origin that result from processes active under permanent water cover. He suggested that the cracks formed after the muds were in a more or less advanced state of compaction because of the changes in the salinity of the water with each successive tide.

In Colorado, montmorillonite clay containing sodium as the exchangeable cation was used to line some of the irrigation ditches. According to R. D. Dirmeyer, Jr., of the Civil Engineering Department of Colorado State University (personal communication, 1962), when fresh irrigation water containing soluble salts of calcium and magnesium was passed through the ditches, the montmorillonite clay developed synaeresis cracks under the irrigation water.

The shale in Vermilion County appears to have polygons and fissures similar to those in the Mississippi River Delta except that the fissures in the shale are filled with carbonates instead of water. The origins of the polygons and fissures were probably more closely related to the synaeresis cracks formed in the clay in the irrigation ditches.

If the shale had been cracked by subaerial dessication, the fissures would have been filled with sand or clay—probably clay because it is the overlying sediment. However, less than 10 per cent of the filling is clay and sand. The greatest bulk of the filling is chemical precipitate.

If the cracks had been formed by subaerial drying, the sides of the fissures would have been parallel, or almost parallel. Some of the fissures do have straight walls, but others have walls that are 3 inches apart at one point and almost come together at other points (Fig. 2A-B).

The cracks or fissures could not have been formed by regional jointing, because some of the fissures meet at an angle of 120°, and the fissures are only about 1½ to 2 feet long (Fig. 2). Six-sided polygons could be made by three sets of regional joints, but the joints would have to continue through, also making triangular polygons with 60° angles next to the 120° angles. Figure 1 shows neither the triangles nor the 60° angles. Three 120° angles originate at one point.

The hypothesis drawn from the results of the study is that the polygons and fissures were produced by synaeresis. The shale probably was deposited as a normal marine shale, except for the top 15 to 20 feet. Instead of having a sufficient percentage of clay minerals deposited with their long dimensions parallel to the bedding to produce a shale with a fissility having a normal fabric index of 0.3 or less (Odom, 1963, p. 55), the top 15 to 20 feet of clay minerals was deposited with almost completely random orientation. Even though the clay has been compacted since Pennsylvanian time, the fabric index is reduced to only 0.47, which signifies almost complete random orientation. The chemical environment could have changed from a sodium-rich environment to one rich in calcium, magnesium, and iron. If such a change had occurred, the shale would be calcareous. Since the shale is noncalcareous, evidently there was a change in the chemical environment, a change in the sedimentation rate, or both.

The top 15 feet of shale exhibiting the polygons contains 10 per cent or less of quartz, whereas the part of the shale 35 to 40 feet below the top contains considerably more quartz. When the top 15 feet of shale was deposited, most of the sediment was composed of clay-size particles.

The velocity of transport and the rate of deposition probably had slowed down by the time the top of the shale member was formed. The clay was deposited in a flocculated state in water with a salt content nearly that of marine waters 15 to 20 feet below the top, as indicated by the marine fossil. The waters could have become less saline as further deposition occurred, but there is no proof of this.

After the deposition of the shale and before the deposition of the underclay above the limestone, the character of the water changed from dominantly sodium chloride to one dominated by ferrous iron, magnesium, and calcium. The change to waters containing a dominance of divalent ions probably began with deposition of the underclay. When the waters containing divalent cations began to replace the sodium chloride waters, the stability of the clay-water system was changed and synaeresis began to pull the particles closer together, forming the polygons and fissures.

Formation of Fissure Fillings

The filling of the fissures began with the precipitation of iron as very tiny crystals of siderite. The crystals were of colloidal size — a tenth, a hundredth, or a thousandth of a micron—and they formed a gel. At the same time, or perhaps a little later, an iron-rich dolomite began to precipitate with the siderite. The latter precipitate seemingly fractured into polygons and cracks. The cracks probably resulted from a change to a water content with more calcium and magnesium and less iron, which is suggested by the fine precipitate in the vein fillings around the siderite polygons. These veins cracked and were later filled with calcite. The cracking may have been the result of the change from waters containing little iron but high in calcium and magnesium to waters high in calcium.

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MINERAL CONTENT IN WATER FROM FIFTY THREE WATER-WELLS IN DEKALB AND SYCAMORE QUADRANGLES, ILLINOIS

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ABSTRACT.—Water samples from 53 selected wells located in the DeKalb and Sycamore quadrangles of northern Illinois were analyzed for mineral content. Total hardness values are related to the kind of aquifer and to the amount and nature of the overlying strata.

The area selected for this study is located in DeKalb and Sycamore Quadrangles, northern Illinois. The wells are located in the townships of Sycamore, Cortland, DeKalb, Malta, and Milan in DeKalb County.

Water samples from 53 selected wells analyzed for mineral content to determine the relation between the total mineral hardness values and the aquifers from which they were pumped. The 53 wells were selected and classified into three types according to the aquifer horizon in which they were based; 38 Galena-Platteville wells, 2 St. Peter and deeper aquifer wells, and 14 glacial drift wells. The 38 Galena-Platteville wells were divided into sub-groups I, II, III, and IV, representing four different aquifers with four different overlying strata situations.

GEOLOGY OF THE STUDY AREA

The glacial drift consists of unconsolidated materials which form a mantle of varied thickness in these five townships. It is thicker along the western edges of the DeKalb Quadrangle and generally thins toward the eastern edge of the Sycamore Quadrangle (a distance of some 18 miles). The maximum thickness of the glacial drift is about 360 feet; the average, about 150 feet; and the minimum, about 15 feet. The reason for this variable depth lies in the preglacial erosional events that provided a general southwestward slope to the preglacial topography. This topography was an expression of erosional effects of the early drainage system known as the ancient Troy River system. The main Troy valley lies somewhat west of the boundaries of the study area, but one of its tributaries underlies this study area as reported by Caldwell in 1962.

All strata studied here dip about 14 feet per mile southeastward. A 50 foot upwarp in this dip trend occurs in the southwest corner of this study area as reported by Caldwell (1962). An indication of the eroded surface may be seen on Figure 1, which gives the relief of this landscape prior to the deposition of glacial drift.

The Niagaran Dolomite is the topmost strata of the buried bedrock surface. This Niagaran Dolomite in the study area occurs as an erosional remnant in portions of Cortland, DeKalb, and Sycamore townships (Fig. 2). Its variation in thickness results from partial chemical and physical removal before the glacier buried the area with drift. The Niagaran Dolomite is a compact dark to light gray dolomite. It serves as a caprock for lower aquifers.

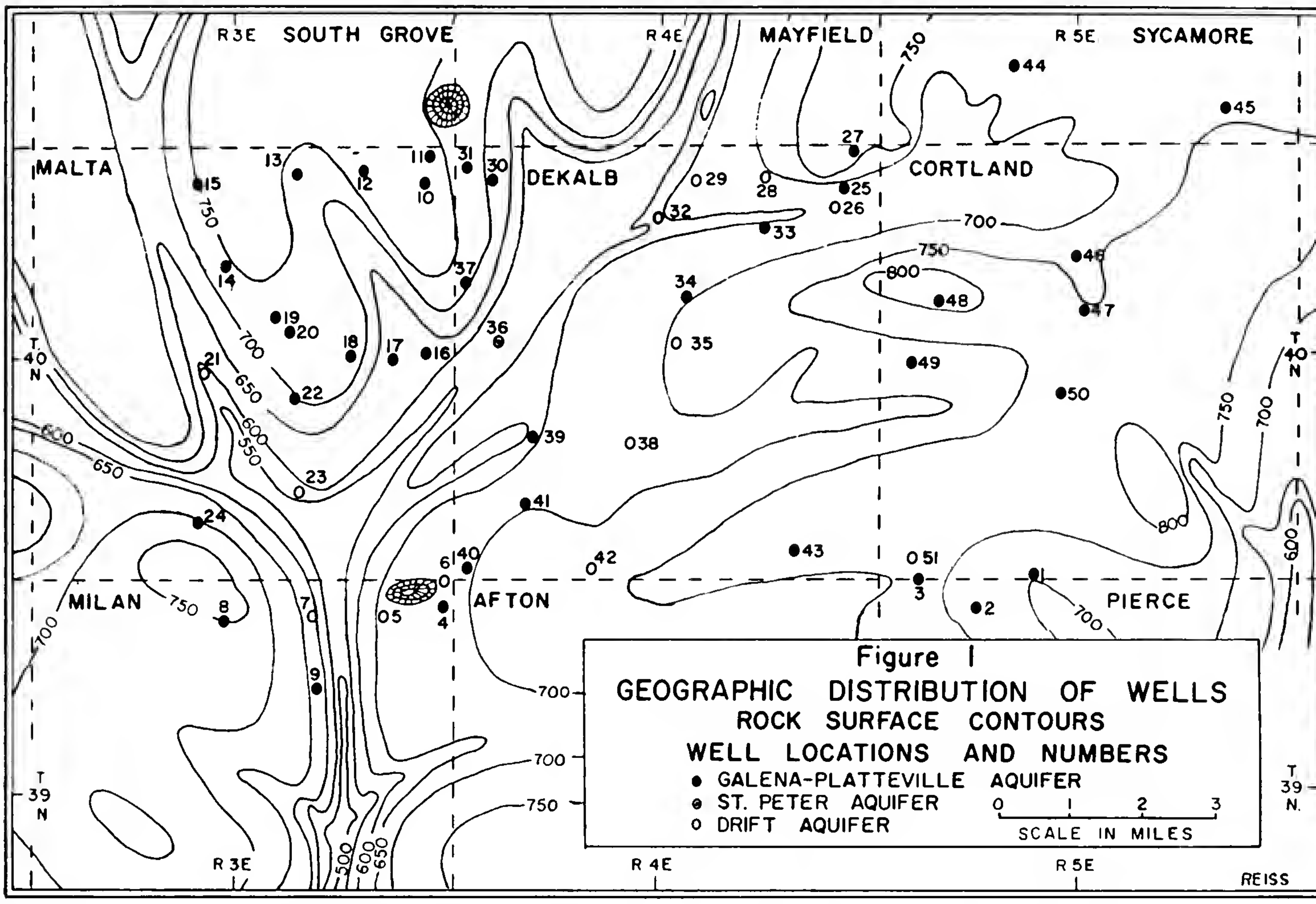

FIGURE 1.—Contour map of bedrock surface showing the study area located in the DeKalb and Sycamore Quadrangles of DeKalb County, Illinois. This map shows the geographic distribution, well numbers, and type of wells.

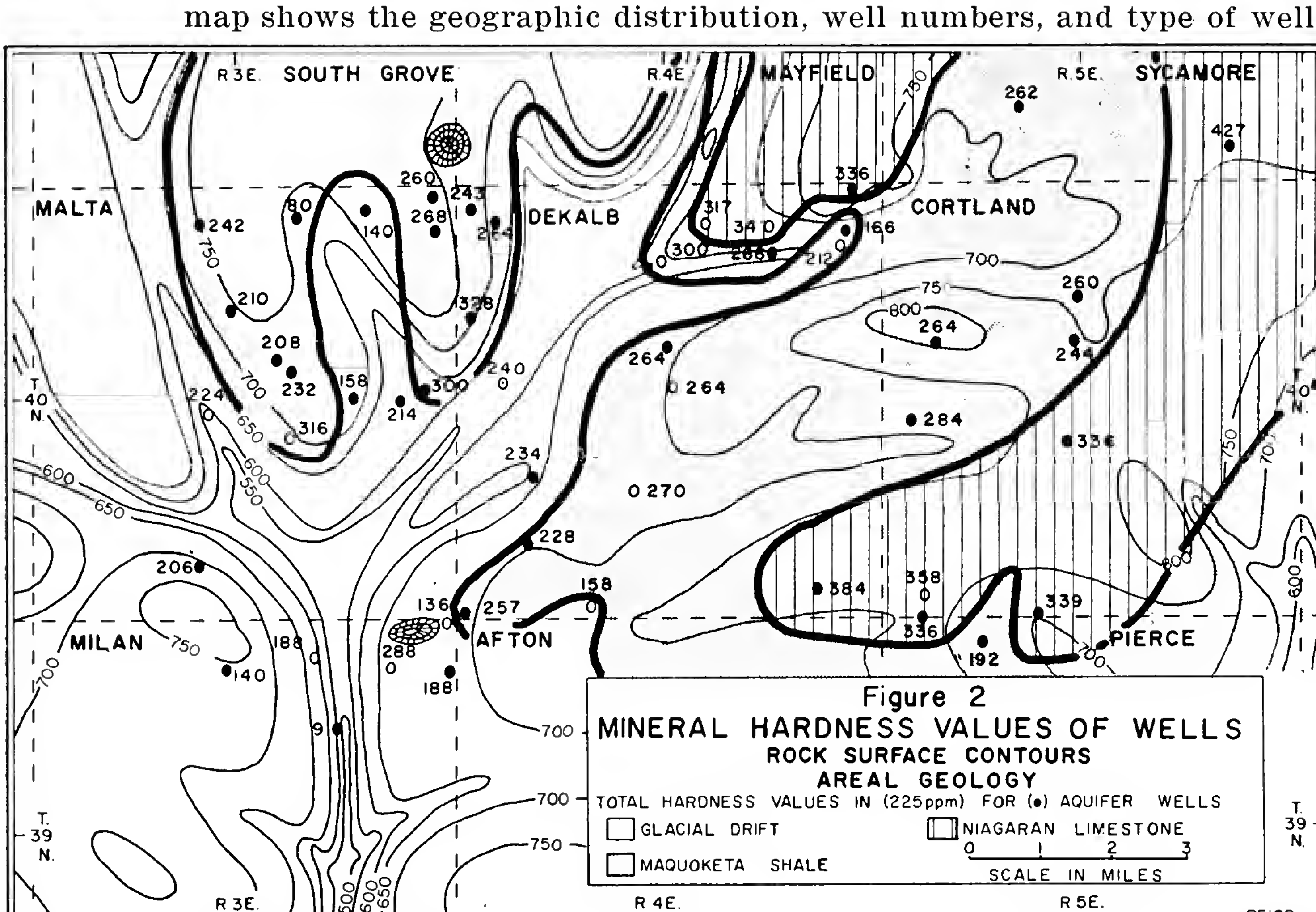

FIGURE 2.—Map showing total hardness values and overlying rock strata for wells located in the DeKalb and Sycamore Quadrangles of DeKalb County, Illinois. The area enclosed by the heavy black line in the upper left part of the figure is Maquoketa Shale.

The Maquoketa Shale, which lies beneath the Niagaran Dolomite has a thickness of 127 feet in the eastern part of the area, changing to zero thickness to the west and southwest. It is composed of calcareous shaly dolomite, compact dolomite, and soft black shale, interbedded with dolomite from top to bottom. It is a partially effective cap rock for lower aquifers.

The Galena-Platteville strata were originally about 345 feet in thickness but locally is less due to preglacial erosion in the western portion of the study area. It is dolomitic, light to dark buff, cherty, and is fine to coarse. It is composed of calcium and magnesium carbonate.

The Glenwood-St. Peter strata lie beneath the Galena and in the area varies from 55 feet in thickness in the eastern part of the study area to 95 feet in the west. The Glenwood Shale is a dolomitic, sandy, silty, argillaceous, grayish green, fine to coarse-grained sandstone. It is friable and contains some gray-brown shale. The St. Peter Sandstone is white, fine-to coarse-grain ed, silty, stained yellow, brown and is shaly. It contains oolites and it is cherty, siliceous, and compact. The top level of the St. Peter aquifer lies at 334 feet elevation in the area of this study. The St. Peter aquifer is separated from the aquifers about it by the impervious Glenwood shale.

This study area has a buried. bedrock topography consisting of the pre-glacial Troy River, located west of this area. The buried Troy River channel lies at an elevation near 400 feet, while the Shabbona Tributary stream, flowing from north to south through the center of the De-Kalb Quadrangle, follows closely along the bedrock surface contact of the Galena and Maquoketa strata. The Galena Dolomite lies west and the Maquoketa Shale lies northeast 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. The Galesville Sandstone aquifer of middle Cambrian in age underlies the entire study area at depths averaging 1300 feet beneath the present surface, as described by Hackett (1960).

Procedure for Gathering Data

Description of wells—The location of the 53 are shown on Figure 1. Each well is cased to bedrock. Thirty-eight wells that terminated in the Galena-Platteville aquifers were chosen. These wells are described on Tables 1, 2, and 3 and total hardness values are given in Figure 2. The analyses of the 53 water samples were made by Solyom (1962, unpublished thesis). The 53 water samples of the study were also analyzed by the laboratories of the Illinois State Water Survey, Urbana, Illinois. The Illinois State Water Survey data was used where differences in data occurred between the two analyses.

The well data for 38 water samples from the Niagaran, Maquoketa, and Galena-Plattevile aquifers are described in Table 1 and their locations appear on the bedrock surface map (Fig. 1). The data of this figure enables a comparison of total hardness (as $CaCO_3$) with aqui-

TABLE 1.—Water Analysis Data from 38 Well Samples Pumped from Galena-Platteville Aquifers. Elevation and Depth Data in Feet.

Township	Well no.	Surface elevation	Well depth	Bottom of well elevation	Elevation of rock surface	Calcium (ppm)	Magnesium (ppm)	Iron (ppm)	Total hardness (ppm)	Total dissolved minerals (ppm)	Alkalinity as $CaCO_3$	Laboratory no. State Water Survey
I. NIAGARAN DOLOMITE—(only overlying strata) Base Elevation approx. 735′												
T39N R5E	3	890	140	750	775	60	45	2.7	336	378	372	160956
T40N R4E	43	810	75	735	760	86	41	3.0	384	410	364	160973
T40N R5E	50	870	110	760	770	70	39	0.6	336	344	332	160965
Average ppm									352			
II. MAQUOKETA SHALE—(only overlying strata) Base Elevation approx. 620′												
T39N R5E	1	880	200	680	760	71	39	7.8	339	372	350	160953
T40N R3E	14	920	180	740	750	41	26	0.4	210	290	274	160718
T40N R3E	15	900	180	720	750	46	31	0.3	242	327	318	160719
T40N R3E	16	900	260	640	650	49	43	0.8	300	356	332	160723
T40N R3E	19	910	200	710	725	32	31	0.6	208	270	276	160726
T40N R3E	22	880	202	678	700	59	41	6.3	316	358	346	160963
T40N R4E	27	840	172	668	750	70	39	2.4	336	340	344	160948
T40N R4E	34	890	200	690	700	44	37	1.1	264	344	331	160731
T40N R4E	37	890	205	685	700	57	45	1.6	328	368	360	160966
T40N R5E	46	860	150	710	725	53	31	4.0	260	300	294	160957
T40N R5E	47	880	210	670	750	44	33	1.9	244	274	285	160955
T40N R5E	48	900	185	715	800	67	23	1.7	264	330	316	160959
T40N R5E	49	900	215	685	720	62	31	1.1	284	347	330	160960
Average ppm									276			
III. MAQUOKETA AND GALENA-PLATTEVILLE—(only overlying strata) Base Elevation 334′ approx.												
T39N R5E	2	880	215	665	725	38	24	0.9	192	264	254	160954
T40N R3E	10	885	485	400	750	48	36	1.5	268	326	320	160709
T40N R3E	11	880	476	404	750	45	36	0.7	260	314	312	160711
T40N R3E	13	905	250	655	750	41	19	0.6	180	258	244	160715
T40N R3E	17	910	550	360	620	43	26	1.3	214	272	260	160724
T40N R3E	20	910	300	610	730	38	33	0.7	232	292	296	160727
T40N R4E	30	880	490	390	700	46	36	1.3	264	316	318	160722
T40N R4E	31	870	225	645	725	44	32	2.3	243	324	306	160951
T40N R4E	33	860	250	610	650	56	36	1.7	286	332	320	160961
T40N R4E	40	870	250	620	700	46	35	1.6	257	350	348	160971
T40N R4E	41	880	275	605	700	42	30	2.4	228	262	276	160970
T41N R5E	44	850	240	610	725	58	28	1.1	262	318	300	160949
T41N R5E	45	850	270	580	740	93	47	13.0	427	504	500	160958
Average ppm									254			

Township	Well no.	Surface elevation	Well depth	Bottom of well elevation	Elevation of rock surface	Calcium (ppm)	Magnesium (ppm)	Iron (ppm)	Total hardness (ppm)	Total dissolved minerals (ppm)	Alkalinity as $CaCO_3$	Laboratory no. State Water Survey
IV. GALENA-PLATTEVILLE—(only overlying strata) Base Elevation 334′ approx.												
T39N R3E............	4	870	420	450	675	40	21	1.6	188	262	256	160714
T39N R3E............	8	870	200	670	750	24	19	0.8	140	224	232	160716
T39N R3E............	9	880	520	360	560	26	16	0.6	132	266	254	160721
T40N R3E............	12	880	196	684	750	31	15	1.1	140	250	220	160712
T40N R3E............	18	910	250	660	720	33	18	0.6	158	232	236	160725
T40N R3E............	24	920	305	615	700	29	32	0.3	206	268	264	160735
T40N R4E............	25	830	385	445	700	41	15	1.1	166	248	236	160710
T40N R4E............	39	890	300	590	650	50	27	2.2	234	284	277	160969
Average ppm........									170			

TABLE 2.—Water Analysis Data from 2 Well Samples Taken from Wells in the St. Peter Aquifer and in the Galesville Aquifer.

Township	Well number	Surface elevation	Bottom of well, elevation	Elevation of rock surface	Well depth	Calcium (ppm)	Magnesium (ppm)	Iron (ppm)	Total hardness	Total dissolved minerals	Alkalinity as $CaCO_3$	Laboratory number State Water Survey
T39N R3E......	36	900	260	550	St.P. 640	46	30	1.6	240	292	296	160732
T39N R3E......	52	880	135	535	Gales. 745	71	38	1.6	332	376	352	160962

fer source and with the overlying strata which covers the aquifers as shown in Figure 2.

The dissolved mineral analysis data from the St. Peter aquifer samples are described in Table 2. The amount of total hardness values are related to depth in this Table.

Data shown in Table 3 describes 13 wells terminating in the glacial drift. These data of total hardness (as $CaCO_3$) are reported along with the well depth and bedrock surface elevations at the well locations. The samples were analyzed for dissolved content of calcium, magnesium and iron compounds by Solyom.

Water samples were collected in bottles, labeled with the owner's name, address, and location. The

TABLE 3.—Water Analysis Data from 14 Well Samples Taken from Various Levels in the Glacial Drift.

Township	Well number	Surface elevation	Well depth	Bottom of well, elevation	Elevation of rock surface	Calcium (ppm)	Magnesium (ppm)	Iron (ppm)	Total hardness	Total dissolved minerals	Alkalinity as $CaCO_3$	Laboratory number State Water Survey
T39N R3E............	5	880	140	740	650	45	28	1.7	228	292	282	160713
T39N R3E............	6	870	147	723	700	26	17	0.3	136	244	226	160720
T39N R3E............	7	880	160	720	600	39	23	0.6	188	276	282	160717
T40N R3E............	21	890	190	700	600	40	34	1.2	240	306	300	160730
T40N R3E............	23	920	305	615	550	30	34	1.0	213	296	274	160734
T40N T4E............	26	840	180	660	655	41	27	1.2	212	312	296	160728
T40N R4E............	28	850	90	770	700	60	40	1.6	314	358	354	160950
T40N R4E............	29	850	80	770	650	57	42	1.1	317	362	348	160952
T40N R4E............	32	870	180	690	650	52	41	0.8	300	352	348	160733
R40N R4E............	35	870	160	710	700	37	42	0.2	264	306	312	160964
T40N R4E............	38	860	100	760	675	50	35	1.8	270	334	324	160967
T40N R4E............	42	860	137	723	750	26	23	1.4	158	208	198	160972
T40N R5E............	51	890	100	790	775	82	37	1.6	358	386	328	160968
T38N R3E............	53	870	000	870	750	134	55	0.1	[1]560	640	384	160729

[1] The total hardness value of well number 53 is 560 parts per thousand. This high total hardness value should be associated with the fact that well number 53 pumps water from the surface in a spring.

bottles were rinsed three times with the water that had been running for several minutes from the well, filled to overflowing, and capped securely.

Water analysis.—The following procedure was employed in water sample analysis. For the determination of total hardness, calcium, and magnesium, the Versenate method was used as described by the American Public Health Association (1961). This is a widely accepted method for the accurate determination of these dissolved minerals in water samples.

These analytical data were recorded on mineral-analysis recording sheets showing the wellowner's name, address, geographical location, and the date of well sampling. Less than half of the pint water samples were used in analyses. The remaining sample is stored with the Northern Illinois University, Department of Earth Sciences.

Interpretation of Data

The three wells of group I were bottomed in the Niagaran Dolomite of the study area. These three water samples are numbered 3, 43, and 50. Their average total hardness is 352 ppm. The Niagaran Dolomite has an average base elevation of 735 feet in the area of these wells. The highest total hardness average was obtained from these wells.

Group II has thirteen wells which are based in the Maquoketa Shale. Their well numbers are 1, 14, 15, 16, 19, 22, 27, 34, 37, 46, 47, 48, and 49. Their average total hardness value is 276 ppm. The average base elevation of the Maquoketa Shale where it occurs in the study area is 620 feet. As reported by Caldwell in 1962, there is a stratigraphic dip in the southwest portion of this study area which brings the base of the Maquoketa Shale to approximately 670 feet. This situation allowed wells numbered 8, 12, and 18 to be in group IV and wells numbered 2, 13, and 31 to be in group III. Well numbered 17 is listed with group III because of its nearness to the margin of the Maquoketa Shale as shown on Figure 2.

Group III has thirteen wells which take water from the Galena-Platteville aquifer with Maquoketa Shale overlying the aquifer. Their total hardness values range from 180 to 286 ppm if well number 45 is excluded from the group. Well number 45 has a total hardness value of 427 ppm which may be due to some local ground water situation which this study did not identify. The base elevation of this Galena-Platteville aquifer is 334 feet.

Group IV has eight wells based in the Galena-Platteville aquifer with no overlying strata. Their total hardness values average 170 ppm.

The thirteen wells based in the glacial drift and the two deep wells based in the St. Peter sandstone and the Galesville Sandstone show no significant total hardness values as related to the aquifers and the overlying strata. Therefore Table 2 and Table 3 are given no interpretation in this study.

Summary

The total hardness values for group I average 352 ppm. Group II water samples have a total hardness average of 276 ppm. Group III water samples have an average total harness of 254 ppm. Group IV water samples have total hardness values with an average of 170 ppm. When these average values are related to the aquifer strata in which each group is bottomed and to the overlying strata for each aquifer, it is apparent that the three wells bottomed in the Niagaran Dolomite with only a glacial drift cover had the highest total hardness average value; thirteen wells bottomed in the Maquoketa Shale with only a glacial drift cover had the second highest total hardness values; thirteen wells bottomed in the Galena-Platteville aquifer with the Maquoketa Shale and the glacial drift overlying the aquifer had total hardness values that averaged 254 ppm which is third in rank. The group IV wells had the smallest total hardness value average of 170 ppm among the four groups of wells in the Type I Maquoketa-Galena-Platteville bottomed wells. These wells were bottomed in the Galena-Platteville aquifer with no overlying strata; only a thick glacial drift cover lay above the aquifer strata. Type II and III wells were given no interpretation in this study.

It seems apparent from the above summary that total hardness values in ground water samples taken from cased drilled wells as selected in this study are significantly related

to the kind of aquifer furnishing the water sample and to the kind and amount of overlying strata above that aquifer.

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A DIRE WOLF SKELETON AND POWDER MILL CREEK CAVE, MISSOURI

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ABSTRACT. — Associated bones of *Canis* (*Aenocyon*) *dirus* were recovered from Powder Mill Creek Cave in Shannon County, Missouri. Radiocarbon tests of the bones give an age of 13,170 ± 600 years B.P. The dimensions of the bones indicate that this individual had limb and foot proportions similar to those of present day wolves and to the large dire wolves rather than the short forearm, shank and feet so characteristic of the smaller specimens found at Rancho La Brea and assigned to this species. A description of Powder Mill Creek Cave and the site of discovery is presented.

In the late fall of 1963, members of the Marion, Illinois, Explorer Post 25 (Boy Scouts of America) discovered several parts of the skeleton of a Dire Wolf, *Canis* (*Aenocyon*) *dirus* Leidy, in Power Mill Creek Cave on Powder Mill Creek in the NE¼ SW¼ part of Sec. 9, T. 29N. R. 2W., Shannon County, Missouri.

After all of the available parts were collected, the ribs were used for a raidocarbon test and the remainder of the material was catalogued under No. P-429 in the Vertebrate Paleontological Research Collection in the Zoology Department of Southern Illinois University.

The opportunity to observe Powder Mill Creek Cave during a period of extreme drought induces me to present more information on the cave than otherwise would be done.

POWDER MILL CREEK CAVE

In the part of Shannon County where this cave is located, the exposed geological section consists of more than 200 feet of Eminence Dolomite (Lower Ordovician) overlain by 15 feet of Gunter Sandstone, and capped by the Van Buren and Gasconade Dolomites. The main channel of the cave is cut in the Eminence Dolomite. In the farther reaches of the cave, crevices extend upward through the Gunter Sandstone and into the overlying dolomites.

The entrance (properly—the exit?) to Powder Mill Creek Cave is located on the east side of the 300-foot ridge that lies, locally, between the Current River and Powder Mill Creek. The cave extends, essentially, in a north-south direction (Fig. 1). It is a wet cave. Before the recent drop in water level, the previously known part of the cave could best be explored by using a canoe. Bridge (1930, p. 49) estimated the flow of water in the cave to be 2½ million gallons a day, and Beckman and Hinchey (1944, p. 70) reported the flow [named Cove Spring for some reason] to be 2,390,000 gallons per day in November, 1942. Such was the situation in 1961. By January of 1964, only a trickle of water issued from the cave and I was able to walk through the heretofore known part of the main channel, passing over shallows, gravel and sandbars, and skirting or wading the larger pools. Presumably, this decrease in the amount of water issuing from the cave can be attributed to the current drought in the Middle West.

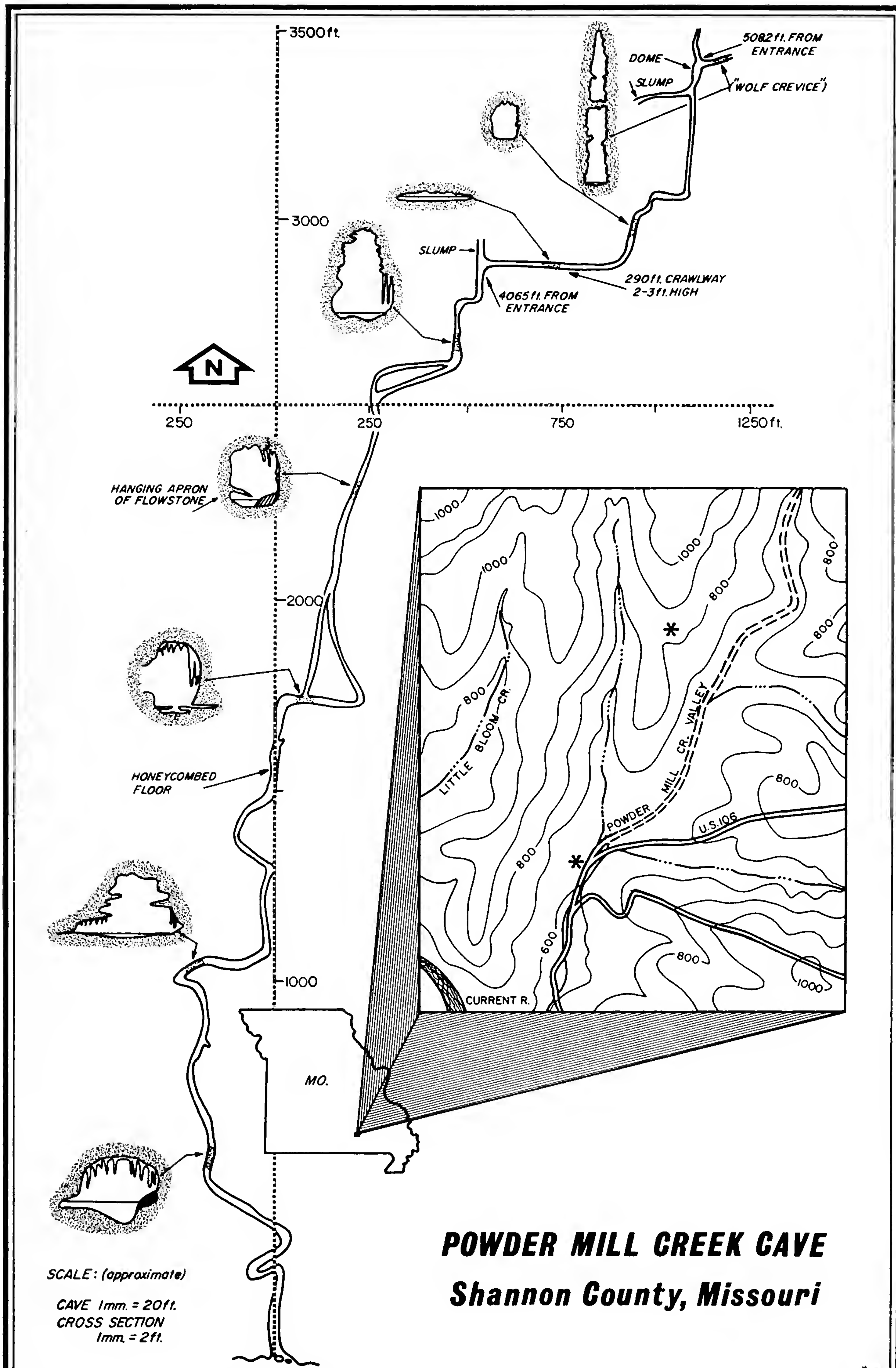

FIGURE 1.—Map of Powder Mill Creek Cave, Owls Bend, Shannon County, Missouri. Inset map, adapted from the Eminence Quadrangle, United States Geological Survey, of area northeast of Owls Bend shows location of Powder Mill Creek Cave. Lower star marks position of entrance in NE ¼ of SW ¼ of Sec. 9, T29N, R2W. Together, the stars mark the approximate position of the part of the cave that has been mapped. Map prepared by Cartographic Office, Southern Illinois University.

Bridge (1930, p. 44) and Bretz (1956, p. 446) described the cave as "small." When compared to caves in Missouri that have large open rooms, this description is just. On the other hand, the temporary low level of the stream in the main channel makes accessible passages that gives a length that can be matched by but few caves in Missouri. In April, 1964, the Marion Explorers and I, using a 300 foot steel tape, obtained a measured distance of 5082 feet plus an estimated additional length that would not exceed 300 yards. Without question, the cave is more than a mile long. The measured distances in the cave may be grouped as follows: from entrance to the beginning of a long (290 ft.) and low (2-3 ft.) horizontal crawlway, 4065 ft.; from the beginning of the crawlway to a crevice (hereafter referred to as the "wolf crevice", Fig. 1), 1017 ft.; from the wolf crevice onward in the main channel, which reduces rapidly in size and is passable by crawling and swimming, not more than 200 yds. It is possible to climb and walk eastward and northward through wolf crevice and an area of honeycombed parent rock for an estimated several hundred yards.

I think the "spring in the cave" referred to by Bridges (1930, p. 44) was the 2½ million gallons of water boiling out of the crawlway and marked the end of the cave at that time.

For the most part, the main channel is broad and tunnel-like with sponge-work, wall and ceiling pockets (some filled with red clay), and a relatively flat or rounded ceiling. Cave "formations" are present, of course, including some remarkable examples of helicites. Two elevated passages lead away from and back to the main channel. The only cross passage is wolf crevice and its mate on the opposite side of the main passage. This cross passage, an obvious product of joint solution, has a rather high, large dome at its junction with the main passage. The western part of this cross passage contains much of the red clay that Bretz (1956, p. 12) regards as a significant feature found in the developmental history of Ozark caves. A massive slump and collapse of the roof has blocked this passage. Possibly it once joined the passage that leads north from the outer end of the crawlway.

Upon entering the "wolf crevice" one climbs up into a narrow, elongate, high (or distressingly deep when it is necessary to creep with a foot on each wall to pass some cavity) crevice and over or through honeycombed parent rock. The crevice might be described as a vertical, elongate maze 50 to 75 feet high and varying in width from inches to many feet, thus being wide or narrow at various levels. Complete and incomplete bridges cross from wall to wall, and, at places, the dissection of the parent rock resembles a massive honeycomb. Great masses of red clay cling to some walls of the crevice.

Red clay deposits, rubble and silt fills, and cave formations contribute to a tendency to distinguish levels in wolf crevice according to the ability of the observer to move through the passageway. Thus discontinuous levels are present and one climbs up or down to a level more conducive to progress. Subsequent to the deposition of the red clay the crevice has undergone alteration by repeated cycles of cut and fill by vadose streams.

The site where the bones were found offers an example of the repeated cycles of deposition and abrasion that took place after the crevice was formed in the parent rock. Extending from wall to wall of the crevice (Fig. 2-3) is a mass of well-eroded Gunter Sandstone, sands, silts, fragments of stalactites, bat bones, and dire wolf bones cemented together in some spots and completely uncemented in others. This mass, about five feet wide, four feet long, and one and a half feet thick, in effect formed a "bridge" across the crevice inasmuch as it now arches over a channel that is open both "upstream and downstream." A remnant of coarse rubble-fill clings to one wall of the crevice below this arch. Some of this rubble bears a striking resemblance to the characteristic gravel of the Ozark streams.

The sandstone that forms the bridge seems to be a solid single piece across the downstream side of the arch, although it is dissected in the area where the bones reposed. Consequently, this relict "bridge" is, in part, a true bridge of parent rock. In all respects the rock appears to be typical Gunter Sandstone. The ascent of the cave passage is relatively regular and certainly is great enough to reach the Gunter. Nonetheless, as presently mapped, the position of the cave in relation to the surface topography requires that the passage go under a small valley and to the area where the Gunter Sandstone has not been removed by erosion. The cave reaches that area but not by a margin that precludes a question of doubt or more investigation.

The sequence of events at the site seem to be as follows:

1. Formation of the crevice with the Gunter Sandstone remaining as a bridge, probably but not necessarily in its present eroded condition.

2. An epoch of red clay fill inferred from evidence of clay in other parts of the crevice.

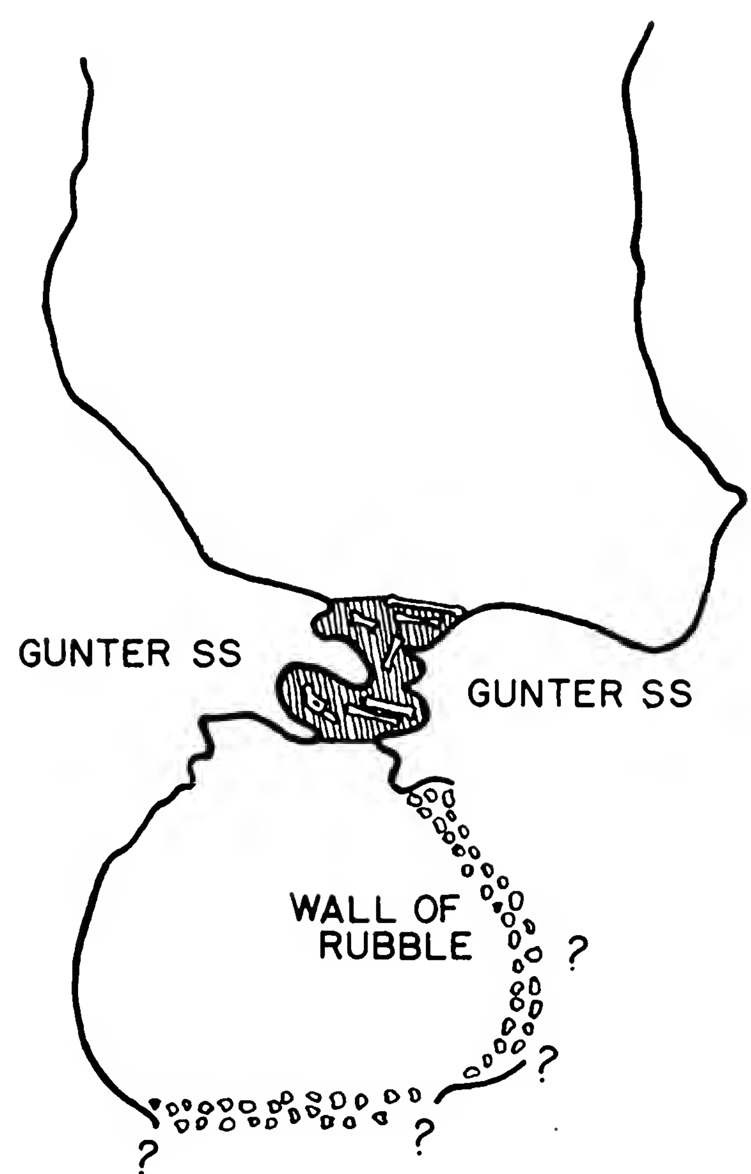

FIGURE 2.—Diagrammatic cross-section of "wolf-crevice" in Powder Mill Creek Cave at the site where the dire wolf was buried, showing the bridge of Gunter Sandstone and uncemented red silt containing free bones and bones cemented to the sandstone, chunks of cemented sandy silt containing bat bones, and fragments of stalactites.

FIGURE 3.—Photograph made by Mr. Robert Blankenship of site during excavation of the dire wolf skeleton. Orientation is essentially the same as that in Figure 2. The individual in the foreground (with back to camera) is peering into the channel below the bridge; the individual not wearing his helmet is kneeling on the "downstream" edge of the bridge. Chest of rotund individual with the cigar obliterates view of area where most of the bones were buried.

3. Removal of red clay in, at least, the immediate area of the bridge.

4. Undetermined number of cycles of abrasion and deposition with the relic mass of rubble under the arch being part of one of the cycles.

5. Filling of the crevice to the level of the sandstone bridge so that a stream of vadose water could carry and lodge the skeleton, debris, and silt in the honeycombed and basined midsection of the bridge.

6. Hypothetical period wherein the accumulation of silts may have continued, covering the bones, or stopped, leaving the uppermost bones exposed as they were at the time of discovery.

7. Removal of the fill, if any, from over the skeleton; removal of the fill, whatever it was, from under the bridge; and removal of enough of the floor of the channel upstream from the bridge to reform a passage under the bridge.

The morphology of Powder Mill Creek Cave well fits Bretz's concept of caves. "Thus Bretz has argued (1942, 1953, 1956) that many phreatic caves may have had three epochs, the one in which the cave developed by solution, the clay-fill epoch, and the one in which the fall of the water table drained the cave. During the third epoch, vadose streams removed part of the clay and vadose dripwater began replenishment." (Bretz and Harris, 1961, p. 15). Bretz (1956, p. 15) listed six features of a cave that he regarded as criteria for identifying a cave formed below the water table—a phreatic cave. Of the six features, Powder Mill Creek Cave has spongework, wall and ceiling pockets, honeycomb structure and bridges. I cannot comment with authority on bedding and joint plane anastomoses or joint determined wall and ceiling cavities in this cave. I do think the rare side passages can be regarded as contributing to an incipient network pattern. The presence of red clay testifies to the existence of the second epoch in the cave's history. The third epoch, characterized by the action of vadose dripwater and vadose streams is evident.

I do not regard Powder Mill Creek Cave to be an isolated unit. Rather, I think it is one segment of a system of caverns of horizontal and vertical extent in this area of northeastern Shannon County. The presence of other caves in the area and the presence of Blue Spring, approximately two miles south-southeast of Powder Mill Creek Cave make an interesting combination of "possibilities" that offers credence to such a supposition. In fact, these observations, at this time, would fit the diagram of a typical cave system presented by Bretz and Harris (1961, Fig. 1).

Subsequent to writing these words, I was pleased to discover that Bridge (1930, p. 40-41) regarded Blue Spring as the outlet for subterranean drainage in the northwest-southeast trough of a shallow, sharply asymmetrical syncline and the gently dipping beds that lead to this trough from the Logan Creek drainage system six miles to the northeast. This conclusion was based on the correlation of the flow from Blue Spring with rainfall that drains into numerous sinks in the upper part of the Logan Creek.

At present, only one entrance is known to the cave, but air currents have been noted in the parts of the cave beyond the site where the dire wolf was found and fresh raccoon tracks have been found in the cross passage. For reasons to be considered below, a high entrance or entrances must have existed in Pleistocene times.

Discovery and Recovery of the Wolf

Powder Mill Creek Cave has been the object of exploration by the Marion Explorers for several years. As the water level in the main channel continued to drop during the early winter of 1963, the crawlway became free enough of water to allow passage into heretofore unvisited parts of the cave. The skeleton of the dire wolf was found by the Marion Explorers during their first visit into wolf crevice. After a second visit, the Scouts had recovered in complete or damaged condition all but thirteen of the parts listed in Table 1. This was evidence that compelled me to visit the site.

As has already been described, the skeleton was buried and subsequently exposed in such a way that it was possible to excavate for bones from above, below, and at the upstream end of the bridge. The evidence at hand suggests that the bones were trapped in the eroded pockets and channel in the Gunter Sandstone and surrounded by red silt. Subsequent to deposition, some of the bones were cemented to the sandstone.

TABLE 1.—Parts of the Skeleton of *Canis* (*Aenocyon*) *dirus* (No. P-429, S. I. U.) Recovered from Powder Mill Creek Cave in Shannon County, Missouri.

Right jaw:	fragments with P_4, M_1, and M_2
Left jaw:	fragments with C (damaged), M_1, M_2, and alveolus of M_3
Atlas:	damaged
Axis:	slightly damaged
Cervical vertebrae No. 3, 4, 5, 6, 7:	slightly damaged
Thoracic vertebra No. ?5:	damaged
Ribs:	fragments of several, most of which were used for a determination of the age
Sternum:	one segment
Scapula:	fragments of right and left
Humerus:	right damaged; left, distal end
Ulna:	right, lacks tip of olecranon process
Radius:	right and left
Metacarpals:	right II, III. IV, and V; left V
Magnum (os capitatum):	right
Pisiform:	right
Innominate:	right, lacks blade of ilium
Femur:	Right and left
Tibia:	left, slightly damaged; and right
Fibula:	left, proximal half
Calcaneum:	left
Astragulus:	left
Cuboid:	left
Navicular:	left
Metatarsals:	left II, IV (proximal end), and V
Proximal phalanges:	seven
Medial phalanges:	five
Distal phalanx:	one
Plantar sesamoid bones:	four

I judge that the bones of the dire wolf were carried into the trap formed by the sandstone before they were completely disassociated. Although in disarray, the parts showed a general orientation that placed the rump of the animal upstream. Parts of the right hind leg were reasonably well-associated so as to suggest that they were bound together by shreds of tissue when buried. The left humerus and pelvis were broken at the time of burial and were among the few bones to be damaged prior to excavation. Not a fragment of bone was recovered that could be a part of the skull. I am sure the lower jaws were complete, when buried, inasmuch as all the recovered fragments show new fracture surfaces; but a most diligent search failed to yield the missing fragments. A Scout is neat, and it is my duty to report that these Scouts kept a neat cave. They dumped the tailings of their digging down a hole!

The evidence of the site and the skeleton suggest to me that the wolf came from "upstream" and was swept to its place of lodgement. This, in turn, suggests that there was a flow of water in the crevice, and that the main channel had a good water supply and was not passable. If such were so, then I presume the wolf entered the cave by some entrance located high above and far from the present known opening.

I cannot resist reviewing the circumstances to which we owe the preservation of this remarkable specimen. To have a goodly part of one dire wolf trapped, to have the segment of fill bearing the bones preserved as it was, and to discover the otherwise unaccessible site during a period of drought seems to be far beyond the reasonable expectations of coincidence.

AGE OF THE BONES

The radiocarbon age determination of these bones, 13,170 ± 600 years, was made by Geochron Laboratories, Cambridge. This age determination is roughly a thousand years less than the possible dates reported by Howard (1960) for pit 3 at Rancho La Brea. Assuming that the age of the dire wolf bones in pit 3 bear a relationship to the age of the tree and tar samples that provided the dates, I would regard the Missouri dire wolf to be essentially contemporaneous (paleontologically speaking) with the dire wolves of pit 3.

Description of the Bones

The known skeletal parts of this specimen of *Canus dirus* resemble those parts of *Canus lupus* in many features. Were it not for proportional differences in size of individual bones when associated together, one would be hard put to prove that the skeleton should not be assigned to *C. lupus.* Differences in the post-cranial skeleton, other than proportional differences, that do exist may or may not be significant, and I question which of such differences could be attributed to being a different species. Nonethless, the following features are recorded.

Size. — Table 2 presents the dimensions of the bones of this individual.

Table 2.—Dimension (in mm) of Parts of the Skeleton of *Canis (Aenocyon) dirus*, No. P-249, Department of Zoology, Southern Illinois University. Except where noted, the measurements are parallel to or perpendicular to a plane of orientation, an axis of the bone, or an axis of the structure named. Measurements marked "est." involve cemented parts or are made from a center line to one side.

Atlas	
Length; plane of trans. processes horizontal	58.0
Width (est.)	113.0
Axis	
Height of axis; plane of post. articular surface of centrum perpendicular	62.0
Length of neural arch; plane of post. articular surface of centrum perpendicular	74.0
Length of neural arch regardless of orientation	74.0
Width of neural arch at post. end (est.)	44.6
Length of centrum from tip of odontoid process to post. articular surface of centrum; plane of post. articular surface perpendicular	73.0
Length of centrum from tip of odontoid process to post. end of centrum regardless of orientation	74.0
Width of ant. articular surface of centrum (est.)	44.0
Height of post. articular surface of centrum (est.)	19.5
Width of post. articular surface of centrum	30.1
Width of trans. processes	55.4
Third Cervical Vertebra	
Height of vertebra; plane of post. articular surface of centrum perpendicular	52.5
Length of neural arch; plane of post. articular surface of centrum perpendicular	55.2
Length of neural arch regardless of orientation	56.4
Greatest width of neural arch	44.4
Width of neural arch at ant. zygapophyses	40.1
Width of neural arch at post. zygapophyses	43.8
Length of centrum; plane of post. articular surface of centrum perpendicular	39.5
Height of ant. articular surface of centrum	17.9
Width of ant. articular surface of centrum	26.8
Height of post. articular surface of centrum	21.4
Width of post. articular surface of centrum	28.4
Width of trans. processes	76.0

Fourth Cervical Vertebra

Height of vertebra; plane of post. articular surface of centrum perpendicular	59.0+
Length of neural arch; plane of post. articular surface of centrum perpendicular	59.7
Length of neural arch regardless of orientation	57.8
Width of neural arch at ant. zygapophyses	50.0
Width of neural arch at post. zygapophyses	45.0
Length of centrum; plane of post. articular surface of centrum perpendicular	36.0
Height of ant. articular surface of centrum	18.8
Width of ant. articular surface of centrum	25.0
Height of post. articular surface of centrum	23.6
Width of post. articular surface of centrum	29.1
Width of trans. processes	70.0

Fifth Cervical Vertebra

Height of vertebra; plane of post. articular surface of centrum perpendicular	68.0
Length of neural arch; plane of post. articular surface of centrum perpendicular	50.0
Length of neural arch regardless of orientation	51.0
Width of neural arch at ant. zygapophyses	51.7
Width of neural arch at post. zygapophyses	46.9
Length of centrum; plane of post. articular surface of centrum perpendicular	32.6
Height of ant. articular surface of centrum	19.1
Width of ant. articular surface of centrum	23.1
Height of post. articular surface of centrum	23.5
Width of post. articular surface of centrum	26.6
Width of trans. processes	64.6

Sixth Cervical Vertebra

Length of neural arch; plane of post. articular surface of centrum perpendicular	43.0+
Length of neural arch regardless of orientation	42.8+
Width of neural arch at ant. zygapophyses	48.1
Width of neural arch at post. zygapophyses (est.)	44.0
Length of centrum; plane of post. articular surface of centrum perpendicular	31.1
Height of ant. articular surface of centrum	21.0
Width of ant. articular surface of centrum	22.1
Height of post. articular surface of centrum	23.9
Width of post. articular surface of centrum	26.2
Width of trans. processes (est.)	62.0

Seventh Cervical Vertebra

Length of neural arch; plane of post. articular surface of centrum perpendicular	42.0
Length of neural arch regardless of orientation	42.0
Width of neural arch at ant. zygapophyses	46.0
Width of neural arch at post. zygapophyses (est.)	41.2
Height of post. articular surface of centrum	21.6
Width of post. articular surface of centrum	28.5
Width of trans. processes (est.)	66.0

Fifth Thoracic Vertebra

Greatest width of neural arch	50.2
Width of articular surface of ant. zygapophyses	19.5
Width of articular surface of post. zygapophyses	17.1
Length of centrum; plane of post. articular surface of centrum perperpendicular	26.2
Height of ant. articular surface of centrum	20.5

Width of ant. articular surface of centrum		23.5
Height of post. articular surface of centrum		20.2
Width of post. articular surface of centrum		22.5
Width of ant. demifacets		32.2
Width of post. demifacets		37.3

Sternebral Element

Length		32.2
Depth at midpoint		18.2
Trans. width at midpoint		9.5

Pelvic Girdle

Orientation: vent. surface of symphysis horizontal.

Length from ant. edge of pubic symphysis to post. end of ischium		110.
Distance between dorsal edges of acetabular lips (est.)		100.
Vertical diameter of acetabular cup		32.7

Teeth

	Left	Right
P-_{4} — M-_{2}, length		65.7
C(lower); anteropost. diameter at base of enamel	18.0	
C(lower); trans. width at base of enamel (est.)	11.8	
P-_{4}, anteropost. length		19.5
P-_{4}, trans. width		9.5
M-_{1}, anteropost. length	34.7	34.9
M-_{1}, trans. width	13.6	13.7
M-_{2}, anteropost. length	13.9	14.0
M-_{2}, trans. width	10.0	10.0

Lower Jaw

	Left	Right
Length, ant. end of ramus to middle of condyle (est. based on ratios of dimensions of known parts to those of other specimens)	233.0	
Depth at a point below the paraconid-protoconid notch of M-_{1} to midpoint of ventral surface of jaw	36.9	
Depth at a point below the hypoconid of M-_{1} to midpoint of ventral surface of jaw	35.5	
Thickness below protoconid of M-_{1}	18.3	

Scapula

	Left	Right
Greatest anteropost. diameter of head	49.7	49.7
Greatest anteropost. diameter of glenoid fossa	40.0	40.0
Greatest trans. width of glenoid fossa	29.+	29.4

Humerus

	Left	Right
Length (est.)		247.0
Anteropost. diameter of head		68. +
Anteropost. diameter of shaft at midpoint		24.5
Trans. width of shaft at midpoint		23.8
Trans. width of distal end	56.2	57.5

Ulna

	Left	Right
Length (est.)		285.6
Length from dist. end to prox. lips of semilunar notch		258.0
Least anteropost. diameter from dist. border of radial facet to prox. lip of semilunar notch		32.5
Trans. width at coronoid process		27.5

Radius

	Left	Right
Length	236.0	235.0
Width of prox. end	31.6	31.3
Width of dist. end	40.9	41.0

Metacarpal II

Length		93.0
Depth of prox. end		19.2
Width of prox. articular surface		11.2
Width of dist. articular surface		14.4

Metacarpal III

Length (est.; surface abraded)		105.0
Width of dist. articular surface		13.5

Metacarpal IV

Length		104.7
Depth of prox. end		18.0
Width of prox. articular surface		12.0
Width of dist. articular surface		13.2

Metacarpal V

Length	92.0	92.0
Depth of prox. end	17.1+	17.3
Width of prox. articular surface	18.4	18.9
Width of dist. articular surface	15.1	14.5

Magnum

Proximodistal length		24.6
Anteropost. depth		16.4
Width		13.0

Pisiform

Anteropost. length		29.0
Depth of prox. end; medial half of ulnar facet horizontal		17.5
Width of prox. end; orientation same as above		18.5

Femur

Length	270.0	270.0
Trans. width of prox. end	66.0	66.0
Anteropost. diameter of shaft at midpoint	21.1	20.9
Trans. width of shaft at midpoint	21.3	21.1
Trans. width of dist. end		55.0

Tibia

Length		265.0
Anteropost. diameter at prox. end		63.+
Trans. width at prox. end		56.+
Trans. width at dist. end	36.5	36.0
Length of fibular scar	122.0	

Fibula

Length (est.)	245.0	
Anteropost. diameter of prox. end	20.5	

Calcaneum

Orientation: same as Figures 1-3, Galbreath, 1955.

Proximodistal length	71.0	
Mediolateral width	30.0	
Dorsoplantar depth	32.0	

Astragalus

Proximodistal length	41.5	
Mediolateral width	34.0	
Dorsoplantar depth	24.0	
Width of body	29.0	
Width of tibular facet	24.2	
Trans. width of head	19.5	
Dorsoplantar depth of head	20.4	

Cuboid

Proximodistal length	30.0
Mediolateral width	22.5
Dorsoplantar depth	22.0

Navicular

Anteropost. length	26.4
Greatest height on outer surface	16.8

Metatarsal II

Length	99.8
Depth of prox. end	21.7
Width of prox. articular surface	9.0
Width of dist. articular surface	13.5

Metatarsal IV

Length (est. based on ratios of existing parts compared to *Canis lupus hudsonicus*)	117.0
Depth of prox. end	19.5
Width of prox. articular surface	15.1

Metatarsal V

Length	104.4
Depth of prox. end	17.2
Width of prox. end including processes	18.0
Width of dist. articular surface	12.5

Proximal Phalanges III and IV

Length, greatest	38.5	39.0	39.7	40.4
Width of prox. articular surface	14.0	13.5	13.5	13.8
Width of dist. articular surface	11.6		10.9	10.9

Proximal Phalanges II and V

Length, greatest		34.6	35.0	35.7
Width of prox. articular surface		13.5	12.7	13.7
Width of dist. articular surface		11.4	10.3	11.3

Medial Phalanges III and IV

Length, greatest			28.6	29.2
Width of prox. articular surface			12.3	11.9
Width of dist. articular surface			12.1	11.8

Medial Phalanges II and V

Length, greatest		23.3	23.7	22.5
Width of prox. articular surface		11.3	13.3	11.4
Width of dist. articular surface		10.6	11.8	10.2

Distal Phalanyx

Length, greatest				27.2
Width at prox. end				11.1
Depth at prox. end				18.1

Individual Age. — The teeth are well-worn and all parts of all the bones are firmly fused. There is no question that this skeleton is that of an adult female.

Disease. — The cuboid and one proximal phalanyx show bony growths similar to exostosis. The growth on the phalanyx may have limited the use of the one toe. Many bones bear roughened eminences for muscle attachments or contact with neighboring bones such as that between the radius and ulna. These eminences seem large and exaggerated when compared to bones of

Canis lupus, yet I cannot think that they are indicative of disease.

Lower jaw and teeth. — The preserved parts of the lower jaw are massive. Unfortunately, the anterior mental foramen is damaged and there is no true indication of its size. It does terminate under the anterior root of P_{-2}. An incipient groove on the postero-lingual side of P_{-4} tends to separate the posterior basal tubercle from the cingulum. However, this separation has not extended to the degree of forming a notch like that described for No. 10727 by Merriam (1912, p. 230). Although well worn, the metaconid of the first molar has one of the secondary tubercles preserved that Merriam (p. 230) regarded as common on the molars of *C. dirus.* The M_{-2} most resembles the tooth depicted in figure 8 of Merriam (1912).

Atlas. — The lateral processes of the atlas are short and stubby, having a posterior border perpendicular to the long aixs something more like that seen in *Canis latrans.* Of the features listed by Merriam (1912, p. 235), this atlas has the large open transverse foramen passing "normally" through the blade, and the transverse processes not projecting far behind the posterior ends of the facets for articulation with the axis. On the other hand, the notches on the anterior border of the processes are deep, well-developed and actually have spines extending toward the midline but not completely enclosing the space. An additional feature of the transverse foramen worthy of note is that the medial border on the ventral side is excavated thus making the nutrient foramen, that runs medial from the canal, open and visible.

Axis. — Merriam described the axis of *C. dirus* as near that of *Canis lupus* in form, differing in certain proportions. The notch on each side of the spine and medial to the tuberosities above each posterior zypopophysis is present. The dorsal border of the neural arch appears to be more flattened than in some of the axes from Rancho La Brea that I have examined or that figured by Merriam (1912, fig. 17). The root of the odontoid process is wide thus, when coupled with the relative shortness of this structure, gives a blunted, conical appearance to the process. The posterior end of the neural arch is bifurcated. The facets for articulation with the atlas are not bluntly rounded on the posterior border but are extended upward and posteriorly thus being comparable with the pattern seen on the axis of *Canis latrans.*

Pelvis. — The pattern of the anterior border of the pelvic canal is like that seen in Recent female wolves, and I do not doubt that this specimen is correctly sexed. The pelves of individuals from Rancho La Brea that I have examined are equally easy to divide into those belonging to males or females. A feature of this and other female pelves that I have seen is the recessed or excavated area for the Obturator internus muscle that lies far posterior to and medial to the borders of the obturator foramen. The depth and extent of the excavation varies in individuals, being 5 to 10 mm deep, and having the borders literally overhanging the area of muscle origin to a greater or lesser entent.

Radius. — The ulnar facet at the distal end of the radius is short and broad. The groove for the tendon of the Extensor ossis metacarpi pollicis is as well-marked as some of those found on specimens from Rancho La Brea. The anterior notch in the margin of the proximal end is deep.

Pisiform. — The lateral corner of the proximal end of this bone projects anteriorly thus producing a "hook" that fitted around the distal end of the ulna.

Metacarpal II. — Merriam (1912, p. 237) reasoned that the narrowness of the medial facet of the scapholunar bone in *Canis dirus* should be accompained by a transversely narrow trapezoid and proximal end on metacarpal II. Such was not the case in the Rancho La Brea specimens or in this specimen from Missouri. The head of metacarpal II is relatively wider than that of *C. lupus hudsonicus.* I am inclined to think that this is a problem involving the size of the individual as well as width and depth of the bone.

Femur. — The medial border of the linea aspera is weak. Insofar as I can ascertan, this is a variable character. The medial crest bordering the patellar groove is greatly enlarged and projects anteriorly far beyond the lateral crest. The greater trochanter is similar to the average condition seen in most of such known bones.

Metatarsal IV. — The articular tubercle on the medial side of the proximal end of metatarsal IV is as large as that seen on similar bones from Rancho La Brea. However, unlike the round, hummocklike, medially directed facet seen normally, only the dorsal surface bears an articular area. Such a condition appears to be intermediate between the structure seen on *C. lupus* and *C. dirus.*

Metatarsal V. — The lateral proximal process of metatarsal V is well-developed here as in Rancho La Brea specimens. On the ventral side only a very weak groove separates this process from the process bearing the articular surface for the sesamoid bone. This latter facet is triangular in shape with the short sides of the triangle on the proximal and medial borders of the process.

Body Proportions

Such body proportions as robustness and relative lengths of the bones of *Canis dirus* have been commented upon by Merriam (1912), Nigra and Lance (1947), and Stock and Lance (1948). Their studies were, of course, based upon a multitude of bones and guided by the sensible idea that big individuals had big bones and medium-sized animals had medium-sized bones (for example see Stock, Lance, and Nigra, 1946). Despite the large size of some of the bones and the recognized variation in length between bones from different pits, *Canis dirus* at Rancho La Brea is, and probably will continue to be, regarded as a homogeneous assemblage. When all the components of the skeleton have been studied in detail and absolute ages determined for each pit, we shall probably realize that the differences in bones from pit to pit are inconsequential. Meanwhile, it is rewarding to have the bones of a single individual that may be regarded as one test of the Rancho La Brea material.

I have prepared Figure 4, after the method demonstrated by Simp-

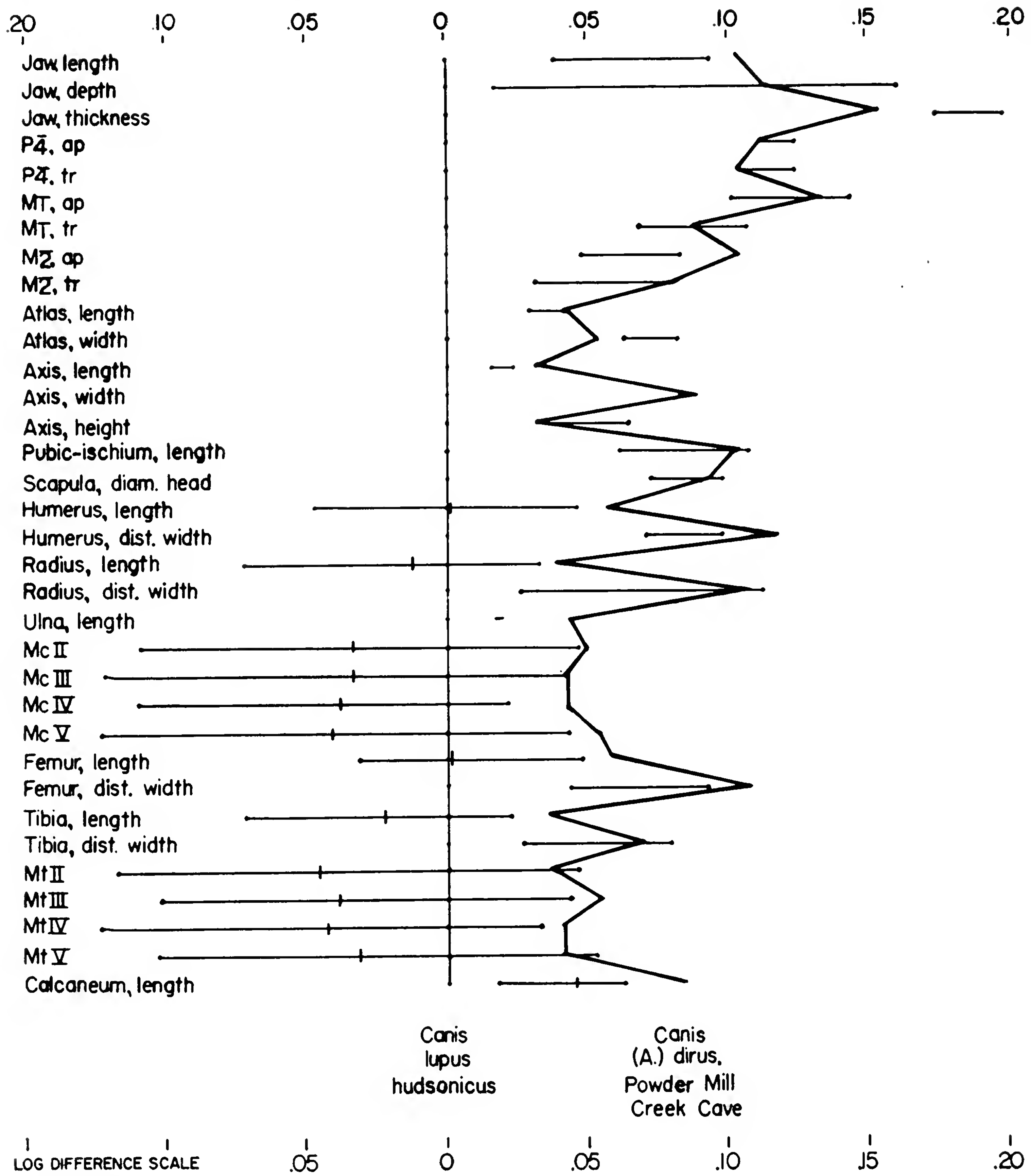

FIGURE 4.—Ratio diagrams (based on a log difference scale) of dimensions of *Canis dirus* from Rancho La Brea Tar Pits, of skeleton of *Canis dirus* from Powder Mill Creek Cave, and skeleton of *Canis lupus hudsonicus* from northern Manitoba (adult female No. 0-1557, Zoology Department, Southern Illinois University).

The ranges of the humerus, radius, femur, tibia, metacarpals, and metatarsals from Rancho La Brea are calculated from the measurements reported by Nigra and Lance (1947) and Stock and Lance (1948). The means reported by these authors are indicated by vertical bars. Other ranges of Rancho La Brea material are based on measurements reported by Merriam (1912) or on measurements made by me. The dimensions of *Canis lupus hudsonicus* were used as a basis for determining the ratios.

son (1941), as a visual demonstration of some of the proportional relationships. Figure 4 is based on measurements taken from Merriam, Nigra and Lance, Stock and Lance, measurements made by me on a small number of bones from Rancho La Brea, measurements of the Missouri skeleton and measurements of an average-sized Recent female wolf. Inadequate as the chart may be in some respects, I think it does present a picture of *C. dirus* that is reasonably reliable, thanks to data collected by Stock, Lance, and Nigra in measuring the limb bones and metapodials from Rancho La Brea.

Inter-memberal proportions. — Dire wolf bones are robust compared to those of Recent wolves. Most of the bones of this specimen from Missouri demonstrate such robustness, to a greater or lesser degree, particularly in having relatively larger dimensions in planes perpendicular to the long axes of the bones. Figure 4 depicts some examples of this condition where the dimensions have been plotted in relation to the length of the structures concerned. While I am convinced that robustness of the bones is one of the features that distinguishes *Canis dirus* from *Canis lupus,* I would hesitate to use this feature to assign isolated, single bones of the post-cranial skeleton to one or the other species. Recognition of the species in special circumstances, such as the metapodials in small individuals as compared to those of the large individuals, emphasizes the need for more study of inter-memberal proportions.

Intra-memberal proportions. — As will be recalled, *C. dirus* is regarded as having a body size ranging from smaller to larger than medium-sized Recent wolves, an inordinately large head, long, deep, and thick lower jaw with a large carnassial, large scapula and pelvis, forearm and shank (epipodial elements) relatively shorter than humerus and femur (propodial elements), and body and extermities more robust. To this body of common knowledge should be added the fact that the calcaneum is proportionately larger. In the past, the feet have been regarded as being relatively smaller in relation to the forearm and shank in contrast to the condition seen in the modern wolf. This is true most of the time; but, the relationship varies with the actual size of the individual. An inspection of the data presented by Nigra and Lance (1947) and Stock and Lance (1948) suggests that within the *C. dirus* entity the metapodials tend to be relatively shorter in smaller individuals and longer in larger individuals. Consequently, the largest individuals and the modern wolves have a similar foot-limb ratio. This new specimen has, from the evidence of the teeth and jaws, a head at least the size of that of medium-sized individuals of *C. dirus* from Rancho La Brea, limbs and body the size of the largest dire wolves, but with metapodials proportionally larger—being near the metapodial to humeral and femoral proportions seen in the Recent wolves. I cannot take an extrapolation of some jaw and teeth measurements of this female too seriously in determining the size of the head. Using the minimal figures, of course, makes the size of the head nearer, relatively, the proportions seen in

Recent wolves. Nonetheless, the parts at hand indicate that the actual size of the head and jaws would yet exceed the size found in the largest Recent wolves, while the body is smaller.

Discussion

When this skeleton was discovered, I assigned it to *Canis* (*Aenocyon*) *dirus* on the basis of the similarity in the size and pattern of the teeth and preserved part of the jaw to specimens from Ranco La Brea, and assumed that I had a good post-cranial skeleton to support the decision. Time has tempered such rash confidence. *Canis dirus* can be distinguished from the Recent wolves by the fact that it has structural differences in the skull, proportionally larger head and teeth, proportionally shorter forearm and shank, and more robust body and extremities. Criteria, other than the structural differences in the skull, are best used together. Used separately, it is necessary to take into account the actual size of the bone or bones concerned or have some associated bones; then only a part of such bones could be identified.

Prime significance may be attached to the proportions of the parts of this specimen from Missouri because they represent the relationships found in the bones of one individual. Furthermore, these proportions match, within reason (that is to say, considering that unknown factor—individual variation), the proportions that exist between the largest bones from Rancho La Brea that have been assigned to the dire wolf. Inasmuch as such proportions do exist, I think it is valid to assume that the large bones from Rancho La Brea belong together. Moreover, the doubt expressed by Nigra and Lance (1947, p. 28) that the largest metapodials included in their sample did not belong to the dire wolf becomes less bothersome.

Table 3 presents a series of indices derived from the relationships between the lengths of the metapodials and the lengths of the epopodial and propodial elements of the extremities of the dire wolf and the Recent wolf. I regard the indices to be of interest more for what they suggest in the way of future problems than as evidence to prove a point. Hildebrand (1952 and 1954) regarded the ratio of metapodial length to epipodial and propodial lengths to be rather constant in the Recent canid skeletons. He did not emphasize individual variation or variation among populations. Obviously, a significant amount of data derived from the bones of associated skeletons of the modern wolves are needed to determine whether or not proportional relationships similar to those found in the dire wolf exist. Any data derived from associated bones of the dire wolf would be welcome. Such data would be a test of the validity of the suggested relationships found in the Rancho La Brea material—particularly if it can be determined that these proportional relationships are unique for the dire wolf.

At present I consider this specimen from Missouri to be a *Canis dirus* and to be reasonably similar to the *Canis dirus* from Rancho La Brea. I think that the material from Rancho La Brea must be regarded as a homogeneous population in the

TABLE 3.—Indices Derived from the Dimensions of Bones of the Extremities of the Dire Wolf and Recent Wolf to Demonstrate Proportional Relationships.

	C. dirus from Rancho La Brea			*C. dirus* from Missouri, No. P-429.	*C. lupus hudsonicus* from Manitoba, No. O-1557	*C. lupus* (average of eight specimens)[2]
	Minimal size[1]	Average size[1]	Maximum size[1]			
Mc III / Radius x 100	39.3	42.	45.	44.5	44.1	43.5
Mt III / Tibia x 100	39.3	40.6	44.3	43.7[3]	43.8	42.5
Mc III / Humerus x 100	36.9	40.4	43.5	42.5	43.9	42.7
Mt III / Femur x 100	36.8	38.9	43.1	42.9[3]	43.4	43.6

[1] Data for indices from Nigra and Lance (1947) and Stock and Lance (1948).
[2] Data for indices from Stock and Lance (1948).
[3] Based on an estimated length of 116 mm for Mt III.

paleontological sense. The variation in size of the metapodials from the different pits, noted by Nigra and Lance (1947), is too little to demonstrate otherwise.

One might argue that having a female as large as the largest Rancho La Brea material would indicate that even larger males probably lived in Missouri. Such a postulation could lead to the suggestion that, compared to the population at Rancho La Brea, a larger subspecies lived in Missouri at a slightly later date. Such a chronocline may have existed but I do not think the present information about *Canis dirus* is useful enough to debate the issue.

COMMENTS ADDED IN GALLEY PROOF

Belatedly, I have discovered the paper by Hawksley, et al. (Missouri Speleology, 5:63-72, 1963) reporting the large dire wolves from Camden and Pulaski Counties, Missouri. Professor William Elder (University of Missouri) and Professor Oscar Hawksley (Central Missouri State College) permitted me to examine the specimens. I think the skeleton (2870; CM 14) from Camden County is that of a large male. The angle between the anterior borders of the pubic rami is acute and the area for the origin of the internal obturator muscle is not recessed. The calcaneum of this individual is 69 mm long (see Hawksley, et al., p. 70) and an unreported left metatarsal II is 110 mm long.

I am impressed by the fact that only large dire wolves have been found in the Ozark region. These specimens, by reason of geographic proximity, could form a hypodigm to accompany Leidy's type of *Canis dirus*. On the other hand, we cannot ignore the evidence of size of individuals from Rancho La Brea when judging the Missouri specimens. Nor am I unmindful of the smaller, and possibly older, dire wolf bones from Frankstown Cave, of *Canis ayersi* Sellards, the several discoveries of isolated parts of dire wolves in North America, and the composition of the genus *Canis* when I join Hawksley, et al. in urging the use of caution in formulating answers to the questions arising from the discovery of these large specimens.

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It is a pleasure to acknowledge the credit due to Mr. Gerald Gotway, a science teacher in the Marion, Illinois High School System for recognizing the value of this find and in obtaining the material for Southern Illinois University.

Words are weak terms to express my gratitude to Mr. Robert Blankenship, and to members of the Marion, Illinois Explorer Post 25 for their help to me in obtaining the skeleton and mapping the cave. It was necessary for Mr. Dee Reynolds, Mr. Dale Norman, and Mr. Gotway, all of Marion, Illinois, to accompany the Explorers. I appreciate the contribution of time and material to the extra trips that were involved. Above all, I shall not forget the kindness, patience, consideration, and genuine solicitude with which I was carefully and tenderly conducted into and out of the cave.

Professor Stanley E. Harris gave much-needed advice on cave work. Authorities and friends at the Smithsonian Institution, University of Colorado Museum, Museum of Natural History, University of Kansas, and Chicago Natural History Museum gave assistance when needed during this study.

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GROWTH OF THE APPENDICULAR SKELETON OF THE MUSKRAT, *ONDATRA Z. ZIBETHICUS* (LINNAEUS)

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Abstract. — **Fusion and growth patterns of long bones of the muskrat in Illinois are described. Subadult and adult skeletons were separated into nine relative age groups by skull development and first upper molar extrusion. Means of the dimensions gathered for each age group were used to estimate relative growth rates. Distal elements of the limbs approach adult size earlier than the proximal elements and the possible use of these latter in age determination is indicated. The sequence of epiphyseal union closely parallels that of the albino rat and the guinea pig. Retarded fusion has a marked effect on growth and proportions of major long bones.**

Although the appendicular skeleton of the muskrat has been described (Latimer and Riley, 1934; Müller, 1953; and Flaim, 1956), studies of postcranial development are lacking. This paper describes growth and fusion of long bones of the muskrat in Illinois.

Materials and Methods

Specimens. The skulls and skeletons of 115 animals, trapped during November and December 1959 in McLean and Iroquois counties, Illinois and two immature specimens taken during the summers of 1960 and 1961 in Montgomery county were used in this study. Skeletons were prepared by macerating the bodies in water. They were stored in cardboard cartons at room temperature and are part of the collections of the Department of Biological Sciences, Illinois State University, Normal, Illinois. Nine known-age muskrat skulls from Iowa (Iowa State University catalogue numbers: 249a, 250a, 251a, 252a, 253a, 254a, 255a, 430a, and 638a) were used as reference in aging. These skulls were also studied by Galbreath (1954).

Age arrangement. Illinois muskrats breed from April to September (Hoffmeister and Mohr, 1957, p. 180); the sample therefore contained in addition to adults, subadults ranging in age from about three to eight months. Determining relative age in the subadults required development of a technique not previously used for aging muskrats. Skulls of the meadow vole (*Microtus pennsylvanicus*) were separated into nine age groups according to the development of certain skull characters by Snyder (1954). Similar changes in age occur in muskrats. Skulls of newly born muskrats have a smooth dorsal surface and lack postorbital processes (Hinton, 1926, plate II). With increasing age, postorbital processes enlarge, lambdoidal and interorbital crests develop, and small bony "horns" appear at the junction of the parietal and squamosal bones (Gould and Kreeger, 1948; Alexander, 1960). Undamaged skulls from 79 muskrat skeletons were examined; those with severely damaged crania were not aged. The postorbital processes on each skull were assigned a value of one, two, three, or four in order of increasing development. Similar values were assigned to a second character-complex, the development of the "horns" and the interorbital crest. The degree of first upper molar extrusion, a valuable age criterion, was assigned a value of two, three, or four; fluting end not visible, barely visible or visible respectively (see Olsen, 1959b). The sum of the three assigned values indicated the skull's relative age (Fig. 1). Nine sums represent nine relative age groups. A total or score of five represented the youngest of the animals trapped during the winter and a score of twelve the oldest. Four, the smallest possible total, fitted skulls of the two immatures collected in the summer.

Composition of each age group was: group four, 1 male, 1 female; group five, 5 males, 5 females; group six, 5 males, 7 females; group seven, 9 males, 4 females; group eight, 3 males, 7 females; group nine, 9 males, 8 females; group ten, 4 males; groups eleven and twelve, 6 males, 5 females.

Age groups eleven and twelve were considered adult because: (1) they alone had adult dentition as described by Gould and Kreeger (1948), Galbreath (1954), Sather (1954), and Olsen (1959b); (2) serious bone disease occurred more frenquently in the two groups; (3) the only specimens with completely fused sacral vertebrae were members of these groups; and (4) a known-age Iowa skull of 571 days was comparable to those of age group eleven. The other Iowa skulls, all subadults of 171 to 222 days, corresponded to age groups six and seven.

Morphological differences and, to a lesser degree, various dimensions of muskrat bacula may be valuable criteria for determining age (Elder and Shanks, 1962). Of 42 male skeletons aged, only 12 bacular shafts were recovered. Measurements were not significantly correlated with the age grouping, but there were definite size and morphological differences between bacula of subadults and adults. Another check on the age grouping was made. The degree of epiphyseal union in long bones, closely corre-

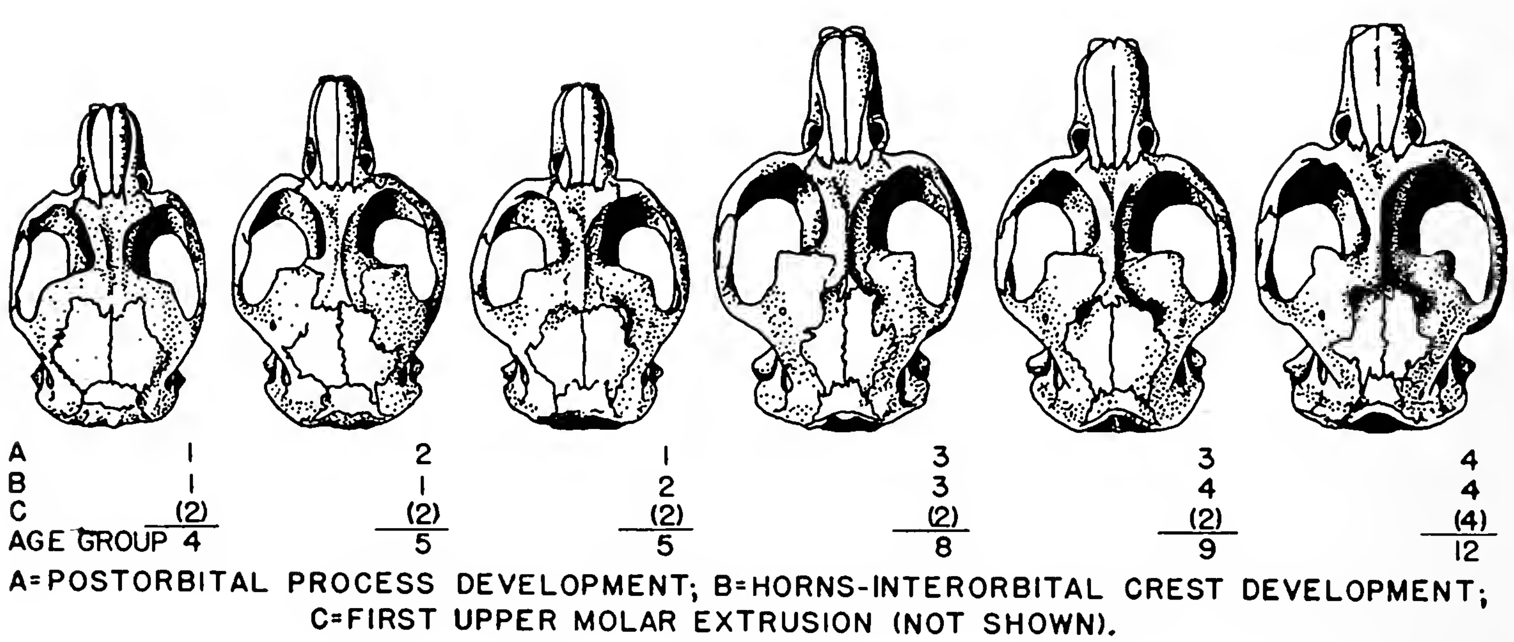

FIGURE 1. — Dorsal view of muskrat skulls and development of characters used in aging (about ½ natural size). From left to right, the age groups are: 4, 5, 5, 8, 9, and 12. Postorbital process development: 1, 2, 1, 3, 3, and 4; horns-interorbital crest development: 1, 1, 2, 3, 4, and 4; and first upper molar extrusion (not shown): 2, 2, 2, 2, 2, and 4.

lated with age, was determined for all skeletons. Only eight of the 79 skeletons aged did not fit their respective groups with regard to the numbers of epiphyses fused. Further study revealed that most of these skeletons also exhibited an irregular sequence of epiphyseal union (see discussion of sequence constancy under *Fusion* below). Whether the differences represent natural variations in the fusion patterns and characters used in aging, an overlapping of the age groups, or abnormal conditions, is unknown.

Measurements. A vernier caliper reading to one tenth of a millimeter was used. Bones were held so that the long axis was parallel with the caliper's back. Measures of left elements were recorded and if unobtainable, the corresponding right dimension substituted. Although Latimer and Riley (1934) stated that the long bones of *O. z. cinnamoninus* were asymmetrical, preliminary work revealed no measurable differences in those of Illinois muskrats.

The ilium was measured from its anterior end to the anterior lip of the acetabulum; the innominate bone, from the iliac crest to the posterior border of the pubis. Dimensions of the calcaneus and clavicle were maximum lengths. Skull measurements were taken in the manner described by Sather (1956): total skull length, from "anterior surface of the incisors to the condylions," and zygomatic width, "greatest distance between the outer surfaces of the zygomatic arches." Other long bone measurements (maximum lengths) were taken in the manner described by Olson and Miller (1958, p. 140-141). Grease content of bones varied considerably therefore weights were not taken.

Maceration destroys cartilage and occasionally detached epiphyses were held against diaphyses while measuring. To check the effect of missing epiphyseal cartilage, long bones from the carcass of a subadult male were defleshed and measured, and after thorough maceration and drying, remeasured. The differences, in millimeters, were: tibia, 0.7; femur, 0.5; humerus, 0.0; ulna, 0.3; and radius, 0.3. All differences were below one per cent of the lengths determined before maceration.

Results and Discussion

Age, sex, and size. Sex differences in rates of body growth were reported by Errington (1939), Dorney and Rusch (1953) and Olsen (1959a). Differences in coefficients of variation of certain skull dimensions were reported by Sather (1956). No sexual dimorphism of skulls was observed when they were arranged by assigned age, sex, size, or the characters used in aging (such as rounded processes versus angular processes). This lack of sexual dimorphism of skulls was also observed by Gould and Kreeger (1948). Many authors have reported differences in absolute size of the animal, males being generally larger. Means and ranges of long bone dimensions of both male and female adults and subadults are given in Table 1. Little difference between sexes of the two ages was observed, but the sample is small. Skull and long bone dimensions increase with age. Skull dimensions are of value in separating subadults and adults (Alexander, 1951). Those of males, age groups five through twelve are shown in Figure 2.

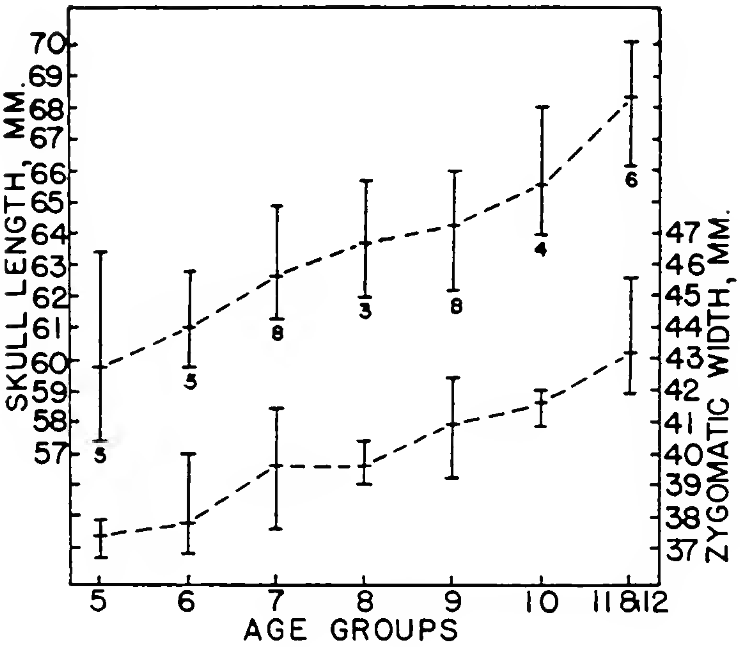

FIGURE 2.— Skull dimensions of male muskrats, age groups 5 to 12. Ranges shown by vertical lines; broken lines connect means; numbers of individuals measured are indicated.

Many techniques for aging muskrats involving measurements (such as upper incisor width, body weight, zygomatic width or breadth, testis length, and penis diameter) show an overlapping of age classes; with larger subadults falling within the adult range (Schofield, 1955). While my data are not sufficient for evaluating the use of long bones as age criteria, the more slowly growing elements may provide a more reliable scale for samples collected during the winter. Table 1 shows little or no overlap between dimensions of adult and subadult innominate bones.

Skeletal growth. Analyses of dimensions revealed similar growth trends in males and females. Trends for males, as revealed by a graphic method developed by Simpson (1941) and Snyder (1954), are shown in Figure 3. The calcanei, third metatarsal, and third metacarpal bones reach adult size earlier. The scapulae and innominate bones grow more slowly.

A growth gradient occurs in the limbs of muskrats. With increasing age, the distal elements (calcaneus, metatarsals, and metacarpals) decrease in the relative percentage they are of the total length of the limb, while the proximal elements (femur and humerus) increase. This is particularly evident in the specialized hind limb (Fig. 4). Muskrats with newly opened eyes and body lengths of not over five inches swim and dive (Johnson, 1925, p. 228; Errington, 1939; Sather, 1958). When they are first able to use the front feet in the diverse manipulations required for building lodges, digging tunnels, opening clams, etc. is not known; but much of the renewed building activity during the fall is credited to the young of the year (Johnson, 1925, p. 269; Smith, 1938). Young of even the slow-growing litters are self sustaining by the end of their first 30 days (Errington, 1939). A few workers, using hind foot lengths, have aged very young muskrats. It seems doubtful, because of this rapid maturation of the distal elements, whether older animals could be similarly aged.

Fusion. With increasing age, epiphyseal cartilage becomes reduced and epiphyses fit their diaphyses more closely. Classes of "closeness of fit" were apparent; fit was either loose and rocking of the epiphysis on its diaphysis evident, or firm with little or no rocking, indicating

TABLE 1.—Dimensions (in mm.) of long bones of muskrats, age groups five through twelve.

Bone		Subadults		Adults	
		Mean	Range	Mean	Range
Innominate	Male	73.9	64.5-82.0 (35)	83.4	82.0-86.0 (6)
	Female	74.1	62.7-81.4 (31)	83.9	82.7-86.8 (5)
Ilium	Male	36.9	32.4-41.2 (35)	42.0	39.4-43.0 (6)
	Female	37.1	31.0-40.7 (31)	41.9	40.7-44.3 (5)
Femur	Male	45.7	39.9-51.0 (35)	51.2	48.0-53.3 (6)
	Female	46.2	40.5-50.4 (31)	51.1	49.9-53.1 (5)
Tibia	Male	63.5	55.0-69.0 (35)	69.9	65.6-71.8 (6)
	Female	64.2	55.9-68.3 (31)	70.6	69.2-73.4 (5)
Calcaneus	Male	17.9	16.0-19.6 (35)	18.8	18.4-19.8 (6)
	Female	18.1	16.8-19.0 (31)	18.6	18.2-19.1 (5)
Metatarsal 3	Male	27.3	24.8-28.9 (34)	27.8	26.7-28.7 (6)
	Female	26.5	25.3-29.6 (30)	27.6	27.0-29.1 (5)
Clavicle	Male	26.5	23.7-29.6 (35)	29.1	27.6-30.9 (6)
	Female	26.8	22.9-28.9 (31)	30.7	30.2-31.7 (5)
Scapula	Male	42.6	36.7-46.8 (33)	46.8	45.8-48.0 (5)
	Female	42.2	35.0-45.9 (28)	47.9	47.0-49.5 (5)
Humerus	Male	37.3	32.8-40.3 (35)	40.8	38.6-42.4 (6)
	Female	37.5	32.9-40.7 (31)	41.4	40.4-42.8 (5)
Radius	Male	39.9	33.2-42.9 (35)	44.0	42.9-44.9 (6)
	Female	39.9	33.9-42.2 (30)	44.3	44.0-45.5 (5)
Ulna	Male	52.1	44.3-56.2 (35)	56.8	55.0-58.4 (6)
	Female	52.4	44.1-55.8 (29)	57.0	55.6-58.9 (5)
Metacarpal 3	Male	10.4	9.9-11.9 (35)	10.8	10.3-11.8 (6)
	Female	10.4	10.1-11.9 (28)	10.8	10.5-11.6 (5)

a more advanced development. The extent of the grooves or "epiphyseal lines" marking a point of fusion also indicate the recency of the fusion; late fusion being represented by deep or sharply defined lines. Epiphyses were ranked according to the number unfused in each age group and the appearance of the junction (epiphyseal lines and closeness of fit criteria). The arrangement closely parallels the sequence of fusion in the albino rat (Dawson, 1925) and the guinea pig (Zuck, 1938) as shown in Table 2. This method, although inadequate for determining an exact sequence, did reveal trends.

Eleven osteologically mature animals were examined and all lacked union in distal epiphyses of the radius, ulna and femur, and proximal epiphyses of the humerus and tibia. Fusion of the epiphyses in the albino

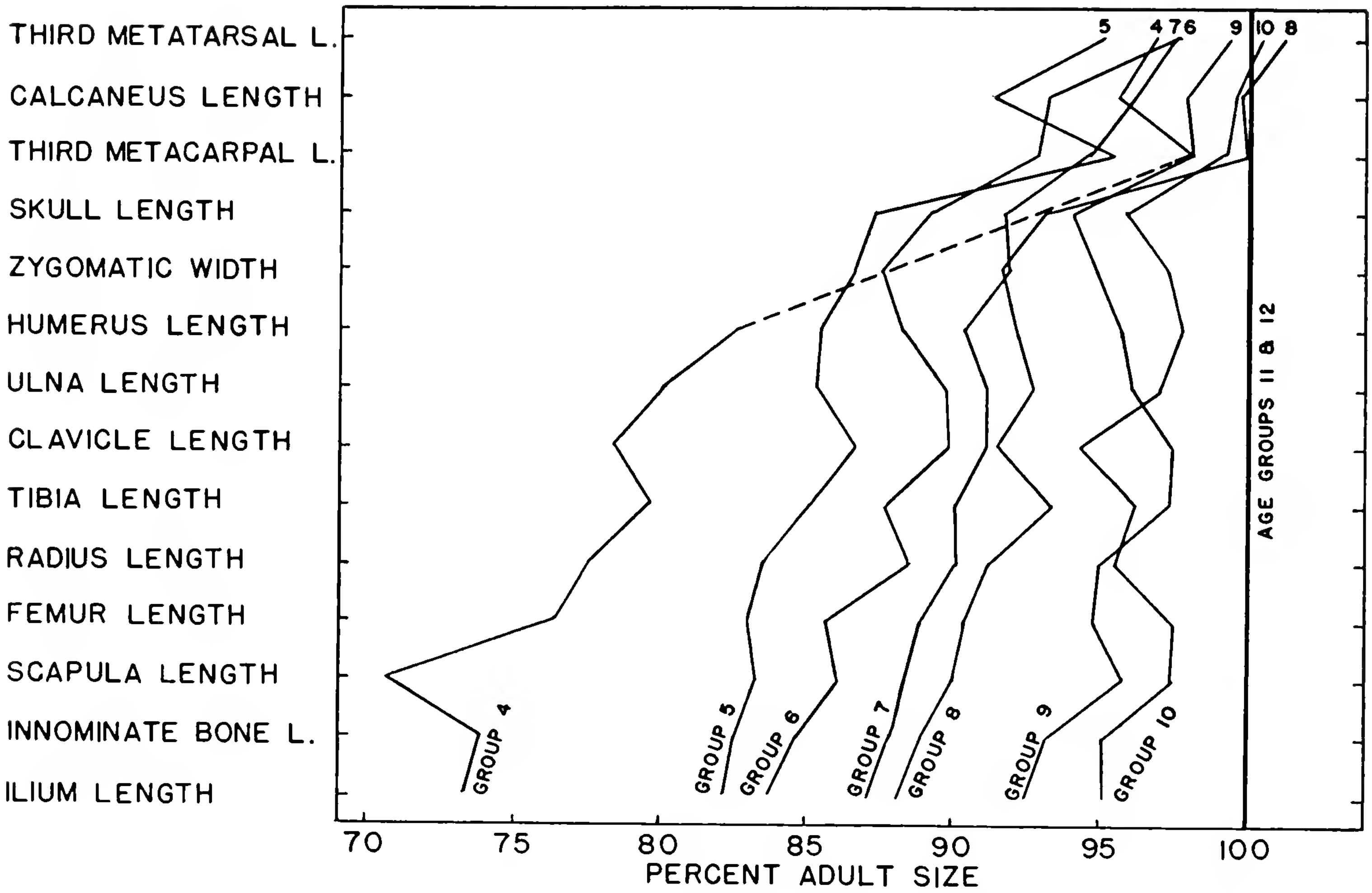

Figure 3. — Percentage of adult size reached by subadult male muskrats. The straight vertical line or 100 per cent coordinate represents mean values of adult dimensions. The points to either side represent mean values of subadult dimensions expressed as percentages of their corresponding adult mean values. Distance between a point and the 100 per cent line represents the percentage of adult size attained.

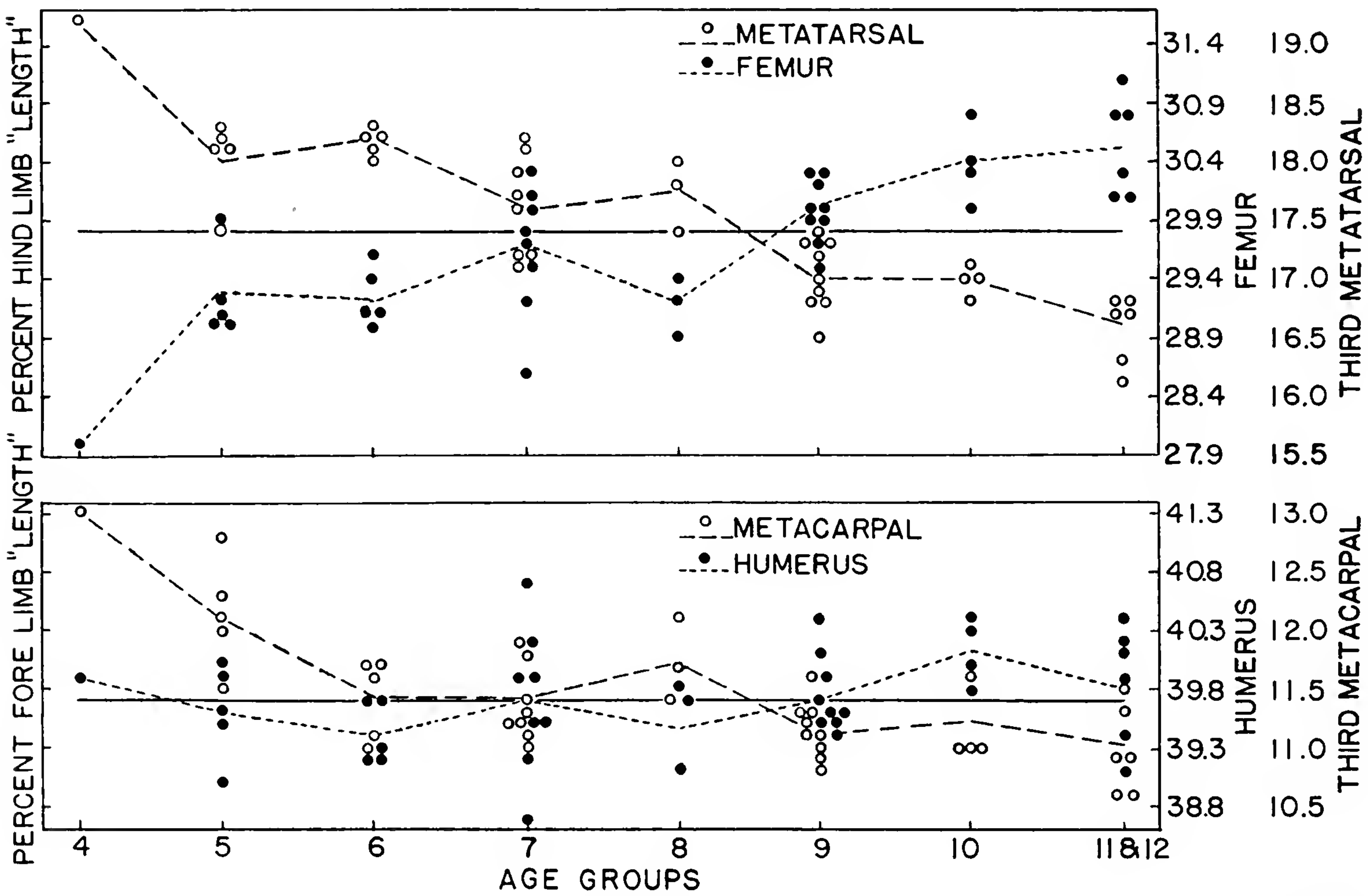

Figure 4. — Age changes in limb proportions of male muskrats. Horizontal scale represents age groups; vertical scale represents percentage that bone lengths are of their respective limb lengths. Broken lines connect means for each age group. Limb "lengths" are sums of bone lengths: femur, tibia, and metatarsal, the hind limb; humerus, radio-ulna average, and metacarpal, the fore limb.

TABLE 2.—Sequence of epiphyseal union in three rodents.

Albino Rat (after Dawson, 1925)	Guinea Pig (after Zuck, 1938)	Muskrat[1]
Dist. Humerus	Dist. Humerus	Dist. Humerus
Prox. Radius		Prox. Radius
	Pelvis, Primary Elements	Coracoid Proc.
		Lesser Trochanter
		Med. Epicondyle, Hum.
	Head, Femur	Metacarpal 3
Dist. Tibia	Dist. Tibia	Pelvis, Primary Elements
Dist. Fibula	Prox. Radius	Dist. Tibia
Hed. Epicondyle, Hum.	Calcaneus	Acromion Proc.
Olecranon	Head, Humerus	Calcaneus[1]
Head, Femur	Metacarpal 3	Head, Femur[1]
Greater Trochanter	Metatarsal 3	Greater Trochanter
	Dist. Femur	Metatarsal 3
	Dist. Fibula	Dist. Fibula
	Olecranon	Olecranon
Dist. Femur		Dist. Femur
Prox. Tibia	Acromion Proc.	Prox. Tibia
Prox. Fibula	Prox. Tibia	Prox. Fibula
Dist. Radius	Dist. Radius	Dist. Radius[1]
Dist. Ulna	Dist. Ulna	Dist. Ulna[1]
Head, Humerus	Prox. Fibula	Head, Humerus

[1] A tentative sequence as explained in text. Sequence of adjacent epiphyses similarly marked could not be determined.

rat occurs during two age periods; from birth to the end of the fifth month, and from the thirtieth month to senility (Dawson, 1925). Since a similar state may exist in muskrats, a tentative order, utilizing closeness of fit data, was worked out. The distal epiphysis of the femur and proximal epiphysis of the tibia were weakly fused in one age group twelve skeleton. While diaphyseal surfaces of these epiphyses are different in contour and shape, 24% of the skeletons had loosely fitting femoral epiphyses and 69% had loosely fitting tibial epiphyses indicating an earlier fusion for the femur. The distal epiphyses of the radius and ulna fit their diaphyses closely in many specimens of several age groups. The head or proximal epiphysis of the humerus, the last to fuse in many mammals, fitted loosely in over 90% of the skeletons examined.

Rate of fusion may vary but the sequence of epiphyseal union is always the same in the human (Stevenson, 1924) and in the albino rat (Dawson, 1925). Correlated evidence suggests that the orderliness also characterizes normal muskrat fusion. But a few skeletons (the same skeletons which did not fit their respective age groups with regard to the number of epiphyses fused) exhibited a curiously irregular sequence. In addition to the epiphyses remaining unfused in all specimens, each of the following remained as the only unfused epiphysis: head of femur, acromion, greater trochanter, distal fibula, and olecranon.

Age limits for fusion of the distal epiphyses of radius and ulna in fox squirrels (*Sciurus niger*) raised in captivity are 54 weeks for males and 50 weeks for females (Carson, 1961). Sex differences in age at time of fusion for various muskrat epiphyses may also exist but no difference in order or sequence was observed.

Flaim (1956, p. 20) stated that the proximal end of the fibula articulates with the peroneal process of the tibia, but I found that the process actually originates on the proximal epiphysis of the fibula which may or may not fuse with the adjacent tibial epiphysis; being unfused in 29 animals of all age groups, fused in 10 animals of age groups eight, nine, eleven and twelve, and weakly fused in 40 animals of age groups five through twelve. Similarly, fusion between distal epiphyses of both bones may also occur, even before they are united with their respective diaphyses.

A cotyloid or acetabular bone was found in three immature skeletons (those of age group four and one of age group five). Fusion between the ramus of the pubis and the ramus of the ischium occurs after the fusion at the acetabulum. The innominate bone enlarges along the posterior borders of the ischium and the pubis as well as at the iliac crest long after union of most epiphyses. Similarly, prolonged growth occurs along the lateral crest or third trochanter of the femur and the deltoid tuberosity of the humerus. The scapula enlarges along the vertebral border.

Proportions. Proportions of various long bones change with increasing age. This was most notable in bones with areas of retarded fusion (Fig. 5). Huxley (1932, p. 40) referred to this lack of fusion in microtinae and the resultant slow growth through adult life. Because epiphyses fit diaphyses so closely in mature muskrats, cartilage, if at all present during life, must be diminutive. Data from known age specimens would be necessary for further analysis of adult growth patterns.

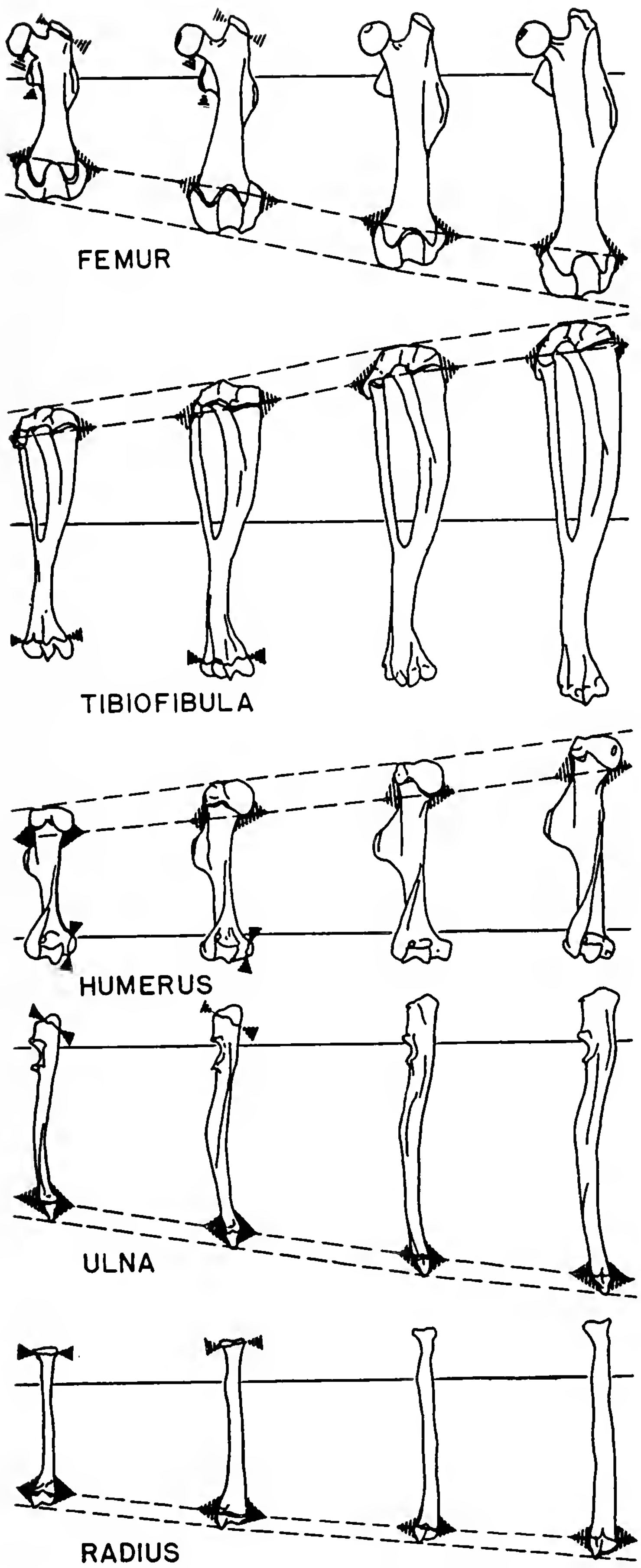

FIGURE 5. — Retarded fusion and related bone growth in bones of (from left to right) two group four immatures, a group seven subadult, and a group twelve adult. Hatching indicates unfused areas. Lateral aspect of ulna, medial aspect of tibia, and extensor surfaces of femur, humerus, and radius are shown (about ½ natural size).

SUMMARY

Seventy-nine muskrat skeletons were separated into nine relative age groups by skull development and first upper molar extrusion. Fourteen linear measurements were taken from major long bones of each skeleton. Means of the dimensions gathered for each age group were used in estimating growth trends. The more specialized distal elements of the limbs approach adult size earlier than the proximal elements. The possible use of dimensions of the innominate bone in age determination is worth more investigation.

The sequence of epiphyseal union in the muskrat closely parallels that of the albino rat and the guinea pig. A lack of union in otherwise osteologically mature skeletons was observed in certain epiphyses. This retarded fusion has a marked effect on growth and proportions of major long bones.

ACKNOWLEDGMENTS

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A KEY TO THE ILLINOIS SPECIES OF *ICTALURUS* (CLASS PISCES) BASED ON THE SUPRAETHMOID BONE

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ABSTRACT. — The species of *Ictalurus* occurring in Illinois can be identified by using diagnostic characters found on the supraethmoid bone.

Diagnostic characters of taxonomic value are present on the supraethmoid bone in the five species of *Ictralurus* occurring in Illinois. Macerated skeletons of the five species (listed in detail in Paloumpis, 1963) of *Ictalurus* in Illinois were studied to determine these diagnostic features. The terms used to describe the structures on the supraethmoid follow the terminology of Kindred (1919). I wish to extend sincere appreciation to Miss Barbara E. Knudsen who made the drawings.

DESCRIPTION OF THE SUPRAETHMOID BONE

The supraethmoid (Fig. 1) is the terminal bone on the dorsal surface of the skull. The ethmoid cornu notch, located in the median anterior edge, is bordered antero-laterally by the body of the supraethmoid. The posterior end of the dorsal surface of the supraethmoid articulates with the frontal bone. The head of the vomer and the parasphenoid articulate on the ventral surface of the supraethmoid.

Several measurements and ratios are used to show differences between the various species. The *width of the supraethmoid* is the distance be-

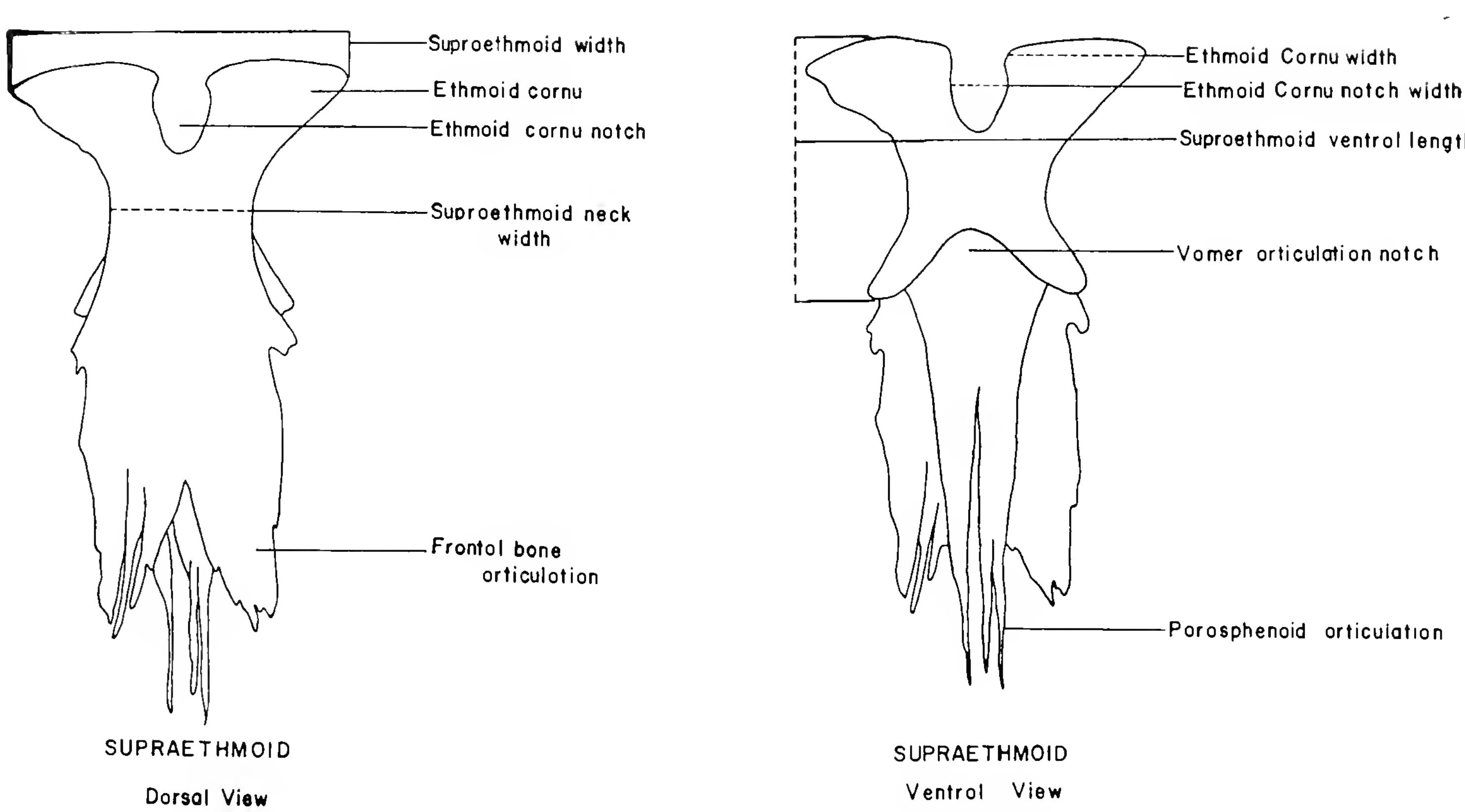

FIGURE 1.—Dorsal and ventral views of a generalized supraethmoid bone of *Ictalurus*.

tween the lateral edges of the ethmoid cornu. The *width of the supraethmoid neck* is the distance through the narrowest portion of the supraethmoid immediately posterior to the ethmoid cornu notch. The *ethmoid cornu width* is the distance from the median edge to the lateral edge of the ethmoid cornu. The *ethmoid cornu notch width* is the greatest distance between the median edges of the lateral projections. The *supraethmoid ventral length* is the greatest distance from the anterior edge of the ethmoid cornu to the posterior edge bordering the vormer articulation.

Ictralurus furcatus (LeSueur)

The ethmoid cornu notch width is equal to or less than the ethmoid cornu notch depth (Fig. 2 A). Supraethmoid width/supraethmoid neck width 0.32-0.33; supraethmoid width/ethmoid cornu width 0.44-0.45; supraethmoid neck width/ethmoid cornu width 0.72-0.75; ethmoid cornu width greater than supraethmoid neck width; ethmoid cornu notch width/ethmoid cornu width 0.51-0.56; ethmoid cornu notch width/supraethmoid width 0.23-0.25; and supraethmoid width/supraethmoid ventral length 0.49-0.56.

Ictralurus punctatus (Rafinesque)

The ethmoid cornu notch width is equal to or less than the ethmoid cornu notch depth (Fig. 2 B). Supraethmoid width/supraethmoid neck width 0.30-44; supraethmoid width/ethmoid cornu width 0.43-0.46; supraethmoid neck width/ethmoid cornu width 0.69—.96; ethmoid cornu width greater than supraethmoid neck width; ethmoid cornu notch width/ethmoid cornu width 0.27-0.41; ethmoid cornu notch width/supraethmoid width 0.12-0.19; and supraethmoid width/supraethmoid ventral length 0.72-0.77.

Ictralurus melas (Rafinesque)

The ethmoid cornu notch width is greater than the ethmoid cornu notch depth (Fig. 2 C). Supraethmoid width/supraethmoid neck width 0.47-0.51; supraethmoid width/ethmoid cornu width 0.38-0.42; supraethmoid neck width/ethmoid cornu width 0.80-0.85; ethmoid cornu width is not greater than the supraethmoid neck width; the supraethmoid width/supraethmoid ventral length 0.27-0.35.

Ictalurus natalis (LeSueur)

The ethmoid cornu notch width is equal to or less than the ethmoid cornu notch depth (Fig. 2 D). Supraethmoid width/supraethmoid neck width 0.52-0.53; supraethmoid width ethmoid cornu width 0.50-0.51; supraethmoid neck width/ethmoid cornu width 0.95-0.97; ethmoid cornu width is not greater than supraethmoid neck width; ethmoid cornu notch width/ethmoid cornu width 0.15-0.18; ethmoid cornu notch width/supraethmoid width 0.07-0.09; and supraethmoid width/supraethmoid ventral length 0.34-0.38.

Ictalurus nebulosus (LeSueur)

The ethmoid cornu notch width is equal to or less than the ethmoid cornu notch depth (Fig. 2 E). Supraethmoid width/supraethmoid neck width 0.40-0.41; supraethmoid width/ethmoid cornu width 0.48-0.49; supraethmoid neck width/ethmoid cornu width 0.87-0.90; ethmoid cornu width greater than supraethmoid neck width; ethmoid cornu notch width/supraethmoid width 0.17-0.18; and supraethmoid width/supraethmoid ventral length 0.57-0.59.

Key to the Five Species of the Genus *Ictalurus* Based on the Supraethmoid Bone

1 A. Ethmoid cornu notch width greater than the ethmoid cornu notch depth; supraethmoid width/supraethmoid neck width 0.47-0.51; supraethmoid width/ethmoid cornu width 0.38-0.42 .... *Ictalurus melas*

1 B. Ethmoid cornu notch width equal to or less than the ethmoid cornu notch depth; supraethmoid width/supraethmoid neck width not as in 1 A; supraethmoid width/ethmoid cornu width greater than 0.42 .... *2*

2 A. Ethmoid cornu width greater than supraethmoid neck width; supraethmoid width/supraethneck width 0.52-0.53; supraethmoid width/ethmoid cornu width 0.50-0.51.. *Ictalurus natalis*

2 B. Ethmoid cornu width not as great as supraethmoid neck width; supraethmoid width/supraethmoid neck width less than 0.44; supraethmoid width/ethmoid cornu width less than 0.50 .... *3*

3 A. Ethmoid cornu notch width/ethmoid cornu width 0.51-0.56; ethmoid cornu notch width/supraethmoid width 0.23-0.25 .... *Ictalurus furcatus*

3 B. Ethmoid cornu notch width/ethmoid cornu width less than 0.50; ethmoid cornu notch width/supraethmoid width less than 0.20 .... *4*

4 A. Supraethmoid width/ethmoid cornu width 0.43-0.46; vomer articulation notch deeper, the supraethmoid width/supraethmoid ventral length 0.72-0.77 .... *Ictalurus punctatus*

4 B. Supraethmoid width/ethmoid cornu width 0.48-0.49; vomer articulation notch shorter, the supraethmoid width/supraethmoid ventral length 0.57-0.59 .... *Ictalurus nebulosus*

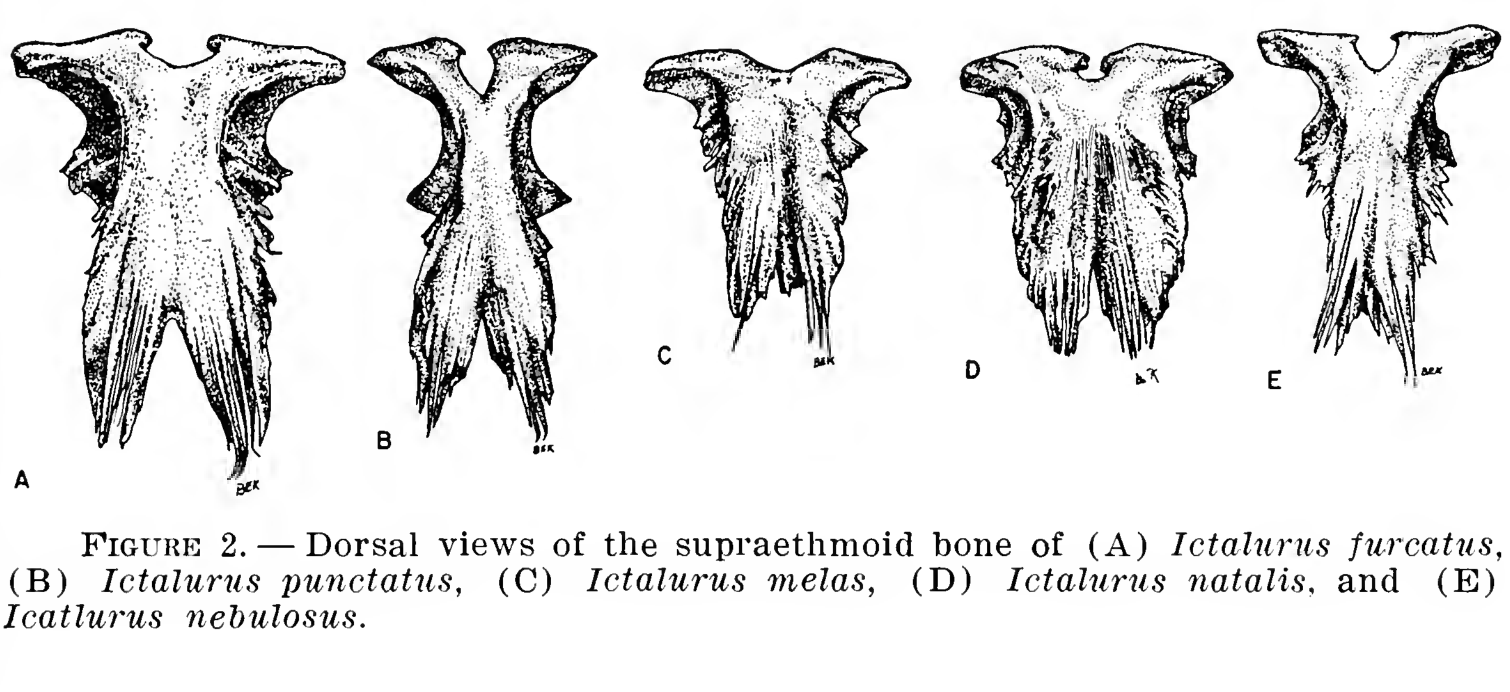

Figure 2. — Dorsal views of the supraethmoid bone of (A) *Ictalurus furcatus*, (B) *Ictalurus punctatus*, (C) *Ictalurus melas*, (D) *Ictalurus natalis*, and (E) *Icatlurus nebulosus*.

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CULTURE, BEHAVIOR, AND THE INDIVIDUAL

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ABSTRACT. — Culture is a reality reflected, somewhat imperfectly, by human behavior.

When we talk of culture, we are referring to a reality as familiar and as casually accepted by each of us as our own personalities. In a real sense culture is a part of us. When I act culturally, I behave according to our culture. If I commit a crime, I do not act culturally even though I perform the act with implements and skills known and utilized in the society. My action is the result of certain "emotions," because of the cast of my personality. Both cultural and anti-social acts are behavior but only the first reflects faithfully the culture.

This close interrelationship of culture and human behavior is a major obstacle to the establishment of a science of anthropology. That culture cannot be observed directly but must be deduced from human activities only serves to make an unclear situation, still more perplexing. The common habit of the anthropologist of passing from culture to behavior and back again in explaining his conclusions serves to confuse the speaker and his audience. For example, the acts of a strong leader and that of a weak one in the same position, at different times, may neither reflect the culture accurately. The stronger leader may exercise more power than the culture sanctions; the weaker may allow others to encroach on powers that are his social responsibility. The cultural norm may be known to the informed native but cannot be derived from overt behavior alone.

Thus culture and behavior belong to two distinct but interlocking natural systems. The failure to recognize behavior as such and to exclude it from generalizations of a cultural nature is largely, in my opinion, responsible for the failure of a general hypothesis, a coordinated "body of scientific theory," to emerge from the numerous studies in social anthropology made down to the present.

Later I shall show that though a man behaves according to the culture he does it as a "free" agent or personality, that is, he acts according to personally held convictions.

Before proceeding further, the realities we are discussing should be formally defined. Terms, to be most helpful to the understanding of the thesis advanced, should be familiar to anthropologists and limited to a single, unequivocal meaning. Thus culture, currently used in several senses, is restricted herein to signify the *system of rules that regulates the behavior of individuals in a society*, as proposed by Radcliffe-Brown (1957, p. 99), Malinowski (1944, p. 40) and Leslie White (1949, p. 144). *Human behavior comprehends the activities of the individual, physical and mental* (perception, interpretation, ideation, synthesis, etc.), in satisfying his needs. [Behavior (to be an entity) includes not only the activity but the urge as well, which arises in the psychobiological structure as the results of a need, and impels the action.]

The operation of a society is behavior, not culture. Cultural behavior is *activity* in conformity to the culture, *not* culture. Proceeding on the assumption that culture is a natural system, it follows that it has laws and principles peculiar to itself (Radcliffe-Brown, 1957 p. 43; L. A. White 1949 p. 123). Culture, therefore, is built around a dynamic agent evidence of which will be found in all its states (F. S. C. Northrop 1959, pp. 343-4). This agent is the human biological structure with its basic needs. Since this is a controversial issue with anthropologists, some further explanation is in order.

Some scientists, like Leslie White, hold that culture is the dynamic factor and man its passive puppet.

> ". . . Culture traits have an existence prior to the birth of any person living. They exist outside the human organism, they act upon him from outside. . . . Man, as an animal organism, as a species, lies within the man-culture system, and there he is the dependent, not the independent variable; his behavior is merely the function of his culture, not its determinant. . . . He exerts no control whatever over his culture . . . Of course culture traits could do nothing were it not for human beings; they could not even exist" (White 1949 pp. 78-79, 350, 99).

Thus White holds that the human brain is a mechanical brain manipulated by culture.

An analysis of a few concrete examples of everyday behavior and the chain of events that lead to the specific action may afford a clearer understanding of the problem. In the United States, a person customarily drives in the right-lane of the highway. A man raises his hat when greeted by a woman acquaintance. A hundred similar examples could be cited. Does culture *make* one drive on the right half of the road, salute a lady by tipping one's hat? Only metaphorically speaking does culture "make" us do anything.

The individual performs these actions. Why? Because he is used to acting thus. He does it without thinking of his culture. Indeed he may not even know he is "controlled" by a culture. He wants to act as he does and would feel uncomfortable if he did otherwise. It is part and parcel of his personality. On the other hand he was not born to act in this manner. He learned it while growing up.

Cultural training of the individual began very early. As a child, he had certain basic urges incident to living—the need for food, for evacuation of waste and so on. To fit into society, he had to learn to perform these natural functions in a manner acceptable to others, that is, in cultural ways. His parents taught him these ways because of the knowledge they had acquired as children from their parents. So the child learned as he matured by precept, example, satisfaction and disappointment, to "know and live his culture." His native urges due to his structure and its needs were modified or conditioned, not by his *culture* but by *cultural training.* These facts are not a mere matter of words, a sophistic splitting of hairs, but show the distinction between culture and behavior. The parts played by culture and human psychology can be summarized thus:

CONCRETE EVENT OR CONDITION	RULE OR ACTIVITY
a. Rules of behavior as recorded in parents brains.	a′. Culture
b. Parents' obligation to act culturally (and train children in cultural behavior)	b′. Parents' Personality (Psychological potentiality)
c. Parents instruct child to behave culturally	c′. Parents behavior
Learning how to behave	Child's behavior
Observing behavior of others	Child's behavior
"Living" the culture—behaving culturally	Child's behavior
d. Rules of behavior & sanction recorded in child's brain.	d′. Culture
e. The obligation to behave culturally—Conscience plus natural urges to satisfy needs	e′. Child's personality

Let us analyze another psycho-cultural concept: cultural change. In this process White believes culture is again the dynamic factor, that cultural development depends primarily on culture, not on the human psychobiological structure.

> ". . . We do not need to take the brains of men into account in an explanation of mathematical [or other cultural] growth and invention . . . There is action and reaction among the various [cultural] elements. Concept reacts on concept; ideas mix, fuse and form new syntheses. This process goes on through the whole extent of culture . . . When this . . . interaction and development reaches a certain point, new syntheses are *formed of themselves*." (White, 1949, p. 292-293. Deuel's italics).

Hallowell opposes White's view of culture determinism and asserts that individuals are the motivating force in cultural change.

> "Although American anthropolgists often speak of the 'movements' of culture or the 'meeting' of cultural traits or complexes, this manner of speaking must be understood as an economical mode of abstract speech. In a literal sense, cultures never have met nor will ever meet. What is meant is that peoples meet and that, as a result of the processes of social interaction, acculturation—modifications in the mode of life of one or both peoples—may take place. Individuals are the dynamic centers of this process of interaction. If perceptible differences in the mode of life of either people result, it means that new ways of acting, thinking, and feeling have been learned by individuals . . . It is hard to see how culture—an abstract summation of the mode of life of a people—can exert an influence except as it is a definable constituent of the activities of human individuals in interaction with each other. In the last analysis it is individuals who respond to and influence one another." (Hallowell, 1945 pp. 175, 174).

This is a case where "both are right and both are wrong." The true situation will be apprehended by tracing the development of a cultural change from the inception of the invention. This is initiated in the brain of an individual for ideas can form there only. The potential invention is put into existence by making the device or engaging in the habit by one individual, then a few until finally it is a generally accepted habit of the people. Up to now it is purely psychological. At the point where it is recognized as a right and proper rule of behavior by the people generally, it is *sanctioned*. Sanction transforms a psychological habit of the group into cultural behavior.

It is sometimes said that a custom diffuses from one culture to another. Does this mean that a culture trait is transmitted bodily to a second culture?

Customs do not move about; they are not transmitted from one society to another, nor are they induced in a culture by their presence in a second culture. In the process of diffusion, a new habit is introduced into the first society, through learning by an individual of the principles of an invention made or used in another culture. (Example: Japanese engineers and scientists learning Western technology and the later incorporation of the exploited techniques into their culture.) Again, the borrowed habit develops among a number of persons in the society and, when finally sanctioned, becomes a custom. Culture change can be analyzed in the following manner:

CONCRETE EVENT OR CONDITION	RULE OR ACTIVITY
a. Invention or learning new habit by individual	a′. Behavior
b. Formation of new habit by a number of people	b′. Behavior
c. Sanction of habit—new custom	c′. Culture

From the foregoing analyses, it is seen that custom formation is foreshadowed in the psychological processes of the brain and in individual behavior. This White freely admits, though as has been seen, he appears to deny any significant psychological contribution of the human biological structure to the syntheses. "These syntheses are, to be sure, real events and have location in time and place. The places are of course the brains of men." (White, 1949, p. 293). But these syntheses are behavior—a mental activity, psychological by its nature—even though the data it works with is culture.

If the foregoing explanation is correct, it has been shown that the individual behaves according to his culture, because his personaitly has been so molded in the family during his formative years. He behaves as he does in conformity to his culture as a "free" agent on account of his convictions and desire that he should so act. Culture has a very real existence, though intangible, in the brains of human individuals, in the brains of most of the people of a society. It consists not only of the system of rules but of the sanction of these rules. Even the criminal conforms to custom most of the time. In fact, in a well integrated society, most of the people obey most of the customs most of the time or it could not operate smoothly (Radcliffe-Brown, 1957, p. 99).

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TRELEASE WOODS, CHAMPAIGN COUNTY, ILLINOIS: WOODY VEGETATION AND STAND COMPOSITION

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Abstract. — An inventory of the woody vegetation of Trelease Woods northeast of Urbana, Champaign County, Illinois shows that the present stand is composed of 149 stems per acre (3″ and above in diameter) with a basal area of 93 square feet. Thirty-seven woody species were tallied with sugar maple being the leading dominant. Hackberry, white ash, slippery elm, basswood, red oak, and buckeye followed in order of Importance Value Index. The large number of dead elm is the most striking feature of the present stand. Total mortality, as indicated by dead-standing and dead-down trees, amounted to 51.5 square feet of basal area per acre; 45 square feet was elm. A heavy understory, dominated by sugar maple and pawpaw, has developed. Almost half of the trees less than one-inch in diameter are sugar maple, and this species appears likely to increase its dominance in the future.

Trelease Woods (formerly known as University Woods) is a 60-acre remnant of the "Big Grove" that once occupied a 10-square-mile area in a bend of the Salt Fork River near Urbana, Illinois. Such forested areas, usually isolated from the main bodies of timber that occurred chiefly along watercourses, were known as "Prairie Groves." They were believed to have been cut off from larger forested areas by attrition from repeated fires and were usually found protected by streams, sloughs, or rough morainal lands.

Trelease Woods was acquired by the University of Illinois in 1917 and has since been maintained as a natural area for research and educational purposes. It has been classified as mixed-mesophytic in composition and probably has developed on uplands that were occupied by prairie grasslands 400 to 600 years ago (Vestal and Heermans, 1945). The first complete inventory of the woody vegetation of this woodland was completed in 1963, and the results are presented in this paper. Results of a similiar study in Brownfield Woods, another remnant of the Big Grove located about one mile to the west, have been reported previously (Boggess and Bailey, 1964). Terminology used throughout the text is that of Gleason (1963).

Past Work

McDougall (1922) made a stem count of the trees and listed the other woody and herbaceous species that occurred in the woodland. His list of species included 31 trees, 12 shrubs, 6 lianas, 134 herbs, and 5 ferns. The number of trees were as follows: *Acer saccharum*, 1,987; *Ulmus americana*, 2,073; *Fraxinus americana*, 537; *Tilia americana*, 321; *Carpinus caroliniana*, 303; and all other species, "less than 300 individuals." Maple was more dominant in the south half, and elm in the north half of the woodland. The general position of these two species, as they occurred in 100 x 100-foot blocks, was also shown on a map of the area. Dominant shrubs were pawpaw (*Asimina triloba*), spicebush (*Lindera benzoin*), and hawthorn (*Crataegus spp.*).

McDougall and Penfound (1928) cited the above paper but gave somewhat different figures for the number of trees and species in the woodland. They listed a total of 7,147 trees comprised of 28 species compared with approximately 5,847 trees and 31 species in the earlier report. That they were quoting from the same data is evidenced by identical figures for the number of American elm, sugar maple, and white ash.

Weese (1924) commented that the woodland had been rather heavily grazed prior to its acquisition by the University and that some trees, particulary black walnut (*Juglans nigra*), had been cut as evidenced by stumps remaining at that time. After five years of protection, however, hardwood species were reproducing in considerable numbers.

Vestal and Heermans (1945), in a study of plot size requirements, reported the number of trees and basal area per acre (trees 3 inches and above, d. b. h.) for the 12 leading species. This was based on data collected between 1935 and 1940 from a 14.4-acre sample. The sample consisted of 10 of 12 plots, 0.8 acre in size, used by Heermans (1941) and a 6.4-acre block in the south half of the woodland, established in 1935 to study the relationships between the size, shape, and distribution of plots and estimates of stand composition (Marberry, 1936; Marberry et al., 1936). The two additional plots in Heermans' study (1941) were included in this block. Thus, it appears that the data of Vestal and Heermans (1945) were biased toward the south half of the woodland.

Numerous studies involving animal populations and ecology have been reported, but most of them are not pertinent to this study. Twomey (1945), however, delineated the areas of "red-oak—maple climax" and "elm sub-climax" as a part of his study of bird populations. He pointed out that although the woodland had been heavily grazed prior to 1918, the woody vegetation had come back to a normal condition after some 20 years of protection.

Methods of Study

All woody plants, 2.6 inches and above in diameter, were measured to the nearest 1/10 inch and tallied by species. Dead-standing and dead-down trees were also measured and identified when possible. Records were kept separately for each of the 96, 50-meter square blocks (0.619 acre) into which the area had been divided for a number of years.

Four sets of nested, circular quadrats, 1/100 and 1/1000 acre in size, were randomly located in each block. The 1- and 2-inch diameter classes were tallied on the larger, and seedlings on the smaller plots. The latter were separated into those less than 1 foot in height and those over 1 foot high but less than 0.6 inch in diameter. For convenience the stock and stand data for the entire woodland are presented on per-acre basis.

Description of Area

Trelease Woods is located in the SW¼ of Section 1, Township 19N, Range 9E, Champaign County, Illinois (40° 09′ N. Lat., 88° 10′ W. Long.). Topography is at the most gently rolling with a maximum difference in elevation of about 16 feet. There are numerous low areas where water stands during wet periods and are moist even in the dry parts of the year. The Woodland is surrounded by open land and has the usual edge vegetation of briars and low shrubs.

A detailed soil survey has not been made, but two main groups are present. These are (1) soils that are transitional between Brunizems and Gray-Brown Podzolic soils, and (2) Brunizem-like soils. The latter group is most prevalent, and the transition soils are minimal in development (Bailey et al., 1964). These soils have all developed shallow loess (3 feet or less) and calcareous glacial till of Wisconsin age.

A detailed description of a transition soil in Trelease Woods, identified as Toronto silt loam, has been given by Bailey et al. (1964). Some of its characteristics are shown in Table 1.

TABLE 1.—Characteristics of Toronto Silt Loam, Trelease Woods.

Horizon	Depth, inches	Sand, %	Silt, %	Clay, %	pH	Organic carbon, %	Cation exchange capacity, meg.	Base saturation %
A1	0-8	3.6	73.0	23.4	6.5	3.83	28.9	92
A21	8-14	3.7	72.2	24.1	5.9	1.92	20.6	80
A22	14-18	3.8	75.3	28.5	5.5	1.56	22.8	77
B1	18-22	4.0	64.2	31.8	5.2	1.36	24.2	76
B21	22-29	4.9	61.6	33.5	5.0	1.20	25.6	72
B22	29-36	13.7	57.4	28.9	5.1	1.22	21.7	75
II B3	36-45	22.4	53.8	23.8	5.8	1.06	16.6	91
II C	45-51	39.2	44.5	16.3	8.1	....	....	Calcareous

The fertility status of this soil is quite favorable as indicated by the cation exchange capacity and base saturation. The profile, however, is imperfectly drained and probably represents the upper level of internal drainage on the area. Poor drainage has undoubtably affected the height growth of trees and has limited the effects of forest vegetation in modifying this soil that was once occupied by grasslands.

RESULTS AND DISCUSSION

Three broad cover types have been recognized on the area (Fig. 1). These are (1) sugar maple, where this species makes up at least 50 percent of the stand; (2) mixed hardwood, in which no single species is dominant; and (3) dead elm. The latter were formerly pure elm and are now in a relatively early stage of succession following death of this species. Areas occupied by each type are about 30, 45, and 25 percent, respectively, for sugar maple, mixed hardwood, and dead elm.

The species encountered, with their density and frequency by size class, are shown in Table 2. The species symbol will be used to identify species in subsequent tables and figures. An additional breakdown into broad diameter classes, by number of trees and basal area per acre for the 13 leading species, is shown in Table 3. Also given are percent

TABLE 2.—Density Per Acre and Frequency of Woody Species by Height or Diameter Class. The species symbol will be used to identify species in subsequent tables and figures.

Scientific name	Common name	Symbol	Height class				Diameter class			
			Density							
			<1′	>1′ <0.6″ diam.	Total	Frequency, %	Density, 1″ & 2″	Frequency, %	Density, 3″+	Frequency, %
Acer saccharum	Sugar maple	SM	1276	1174	2450	52	114	41	37.81	96
Fraxinus americana	White ash	WA	151	36	187	6	8	4	10.38	96
Quercus rubra	Red oak	RO	188	34	222	13	0.3	0.3	2.81	70
Celtis occidentalis	Hackberry	H	255	115	370	16	32	18	20.90	96
Tilia americana	Linden, basswood	L	13	3	16	1	23	9	11.99	85
Quercus macrocarpa	Bur oak	BO	55	36	91	7	2	2	1.61	47
Juglans nigra	Black walnut	BW	.....	21	21	2	7	4	3.96	70
Aesculus glabra	Buckeye	B	96	42	138	6	24	16	7.86	92
Ulmus rubra	Slippery elm	SE	70	55	125	6	44	17	17.96	96
Fraxinus quadrangulata	Blue ash	BA	29	52	81	4	11	8	2.86	66
Quercus Muhlenbergii	Chinquapin oak	CO	89	31	120	8	.....	.....	0.40	19
Gymnocladus dioica	Ky. coffee tree	CT	.....	5	5	0.5	3	2	1.41	30
Ulmus americana	American elm	AE	5	8	13	1	8	4	4.16	56
Platanus occidentalis	Sycamore	S	.....	.....	.....	.....	.....	.....	0.13	7
Carya ovata	Shagbark hickory	SH	3	5	8	1	0.5	0.5	1.01	20
Gleditsia triacanthos	Honey locust	HL	.....	5	5	0.5	7	4	0.38	10
Carya cordiformis	Bitternut hickory	BH	23	26	49	3	3	2	0.52	24
Acer saccharinum	Silver maple	SiM	.....	.....	.....	.....	.....	.....	0.14	1
Fraxinus pennsylvanica	Green ash	GA	16	26	42	3	5	3	0.19	3
Morus rubra	Mulberry	M	3	.....	3	0.3	1	0.8	0.38	12
Prunus serotina	Black cherry	BC	.....	10	10	0.5	0.5	0.5	0.09	4
Quercus imbricaria	Shingle oak	SO	.....	.....	.....	.....	.....	.....	0.02	1
Crataegus mollis	Hawthorn	HT	3	3	6	0.5	8	4	6.71	58
Asimina triloba	Pawpaw	PP	112	570	682	31	480	55	9.08	55
Carpinus caroliniana	Blue beech	BB	23	5	28	1	11	6	5.67	67
Maclura pomifera	Osage orange	OO	.....	.....	.....	.....	.....	.....	0.12	3
Prunus americana	Plum	P	.....	.....	.....	.....	.....	.....	0.13	1

Prunus virginiana	Choke cherry	CC	3	3	6	0.5	24	16	0.07	10
Cercis canadensis	Red bud	RB	3	....	3	0.3	0.5	0.3	0.08	5
Lindera benzoin	Spice-bush	SB	608	94	702	16	89	18	0.03	2
Cornus racemosa	Gray dogwood	GD	3	....	3	0.3	2	1	0.02	2
Euonymus atropurpureus	Wahoo	W	23	8	31	2	....	....	....	....
Staphylea trifolia	Bladder-nut	BN	10	8	18	1	3	0.3	....	....
Zanthoxylum americanum	Prickly ash	PA	52	128	180	2	....	....	....	....
Viburnum lentago	Nannyberry	NB	5	3	8	1	1	0.3	....	....
Sambucus canadensis	Elder	E	16	5	21	1	0.5	0.5	....	....
Corylus americana	Hazelnut	HN	42	23	65	2	....	....	....	....
Total	....	....	3175	2534	5709	....	912.3	....	148.88	....

TABLE 3.—Number of Trees, Basal Area Per Acre, Importance Value Index, and Average Diameter for Leading Dominants.

Species	3-6		7-12		13-24		25-26		37+		Total		Percent Total		Impor. Value Index	Av. diam., in.
	No.	B.A.	No.	B.A.	No.	B.A.	No.	B.A.	No.	B.A.	No.	B.A.	No.	B.A.		
SM	16.26	1.31	10.15	5.17	10.49	16.80	0.84	3.62	0.07	0.59	37.81	27.49	25.39	29.52	54.91	11.5
WA	3.90	0.37	1.30	0.60	4.65	8.88	0.53	2.16	......	......	10.38	12.01	6.97	12.90	19.87	14.3
RO	0.11	0.01	0.03	0.01	0.91	2.10	1.66	8.31	0.10	0.80	2.81	11.23	1.89	12.07	13.96	27.1
H	14.45	1.49	4.73	1.89	1.07	1.79	0.59	2.74	0.06	0.56	20.90	8.47	14.03	9.10	23.13	8.6
L	7.90	0.69	2.12	0.95	1.64	2.83	0.33	1.54	......	......	11.99	6.01	8.05	6.46	14.51	9.6
BO	0.18	0.01	0.13	0.07	0.62	1.17	0.62	3.10	0.06	0.66	1.61	5.01	1.08	5.38	6.46	23.9
BW	2.09	0.25	0.13	0.07	1.27	2.57	0.47	2.04	......	......	3.96	4.93	2.66	5.30	7.96	15.1
B	4.79	0.38	0.96	0.48	2.04	3.46	0.07	0.28	......	......	7.86	4.60	5.28	4.94	10.22	10.4
SE	16.19	1.40	1.16	0.43	0.55	0.96	0.06	0.25	......	......	17.96	3.04	12.06	3.27	15.33	5.5
BA	1.06	0.10	0.79	0.36	0.91	1.59	0.10	0.51	......	......	2.86	2.56	1.92	2.75	4.67	12.8
CO	......	......	0.03	0.02	0.22	0.43	0.11	0.57	0.04	0.36	0.40	1.38	0.27	1.43	1.70	25.1
CT	0.82	0.08	0.23	0.11	0.34	0.65	0.02	0.08	......	......	1.41	0.92	0.95	0.99	1.94	10.9
AE	3.62	0.32	0.45	0.16	0.05	0.06	0.04	0.22	......	......	4.16	0.76	2.79	0.82	3.61	5.8
Others	22.58	1.69	1.11	0.43	0.80	1.32	0.24	0.88	0.04	0.37	24.77	4.69	16.66	5.07	21.73	5.9
Total	93.95	8.10	23.32	10.75	25.56	44.61	5.68	26.30	0.37	3.34	148.88	93.10	100.00	100.00	200.00	....

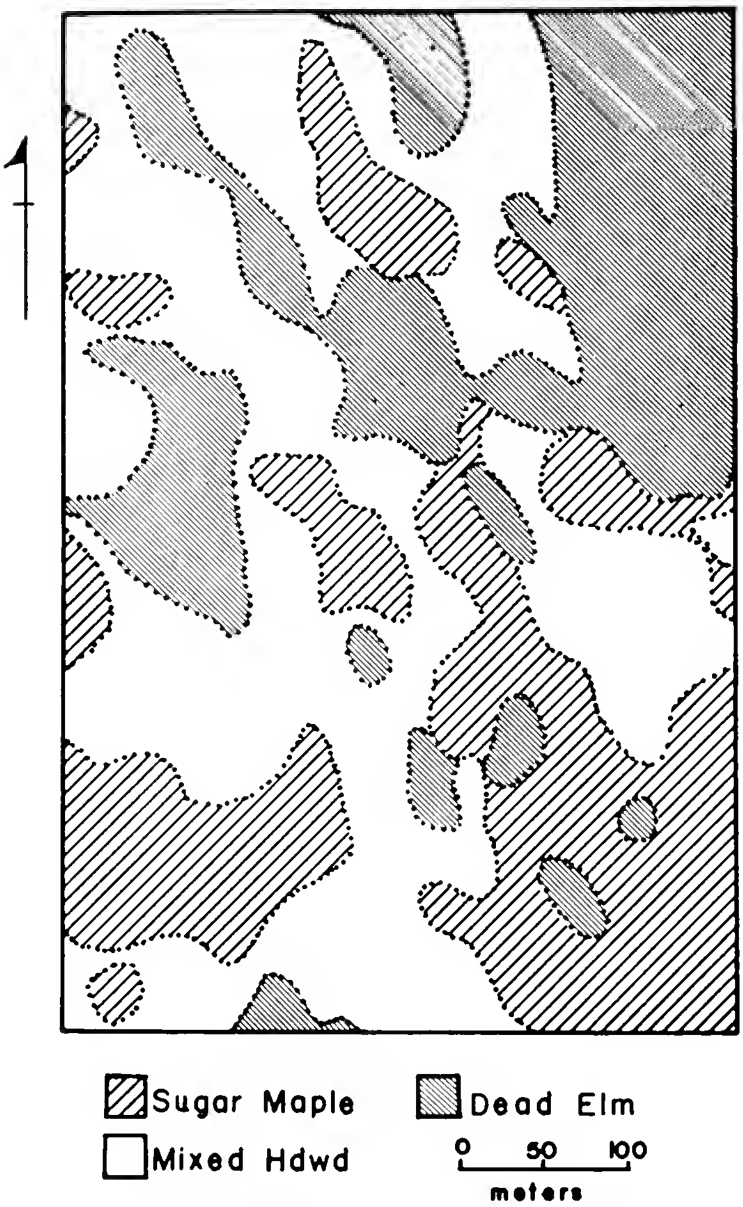

FIGURE 1. — Map Showing Broad Cover Types.

total number of trees, percent total basal area, Importance Value Index (IVI) and average diameter. Importance Value Index is a modification of the original IVI described by Curtis and McIntosh (1951), and used later by McIntosh (1957). It is the sum of the relative density

$$\left(\frac{\text{number individuals of species}}{\text{number individuals of all species}} \times 100\right)$$

and of the relative dominance

$$\left(\frac{\text{basal area of species}}{\text{total basal area all species}} \times 100\right).$$

IVI was determined for the 13 leading species on each of the 96 blocks and for the woodland as a whole.

Present stand composition, as illustrated in Figure 2, shows the number of trees per acre and the average basal area per tree for the 13 leading species, and for all other species combined. In such composition diagrams, the basal area per acre is represented by the area included in each bar of the graph (Vestal, 1953). A further representation of stand structure is shown in Figure 3, where total basal area and the amount of basal area in five

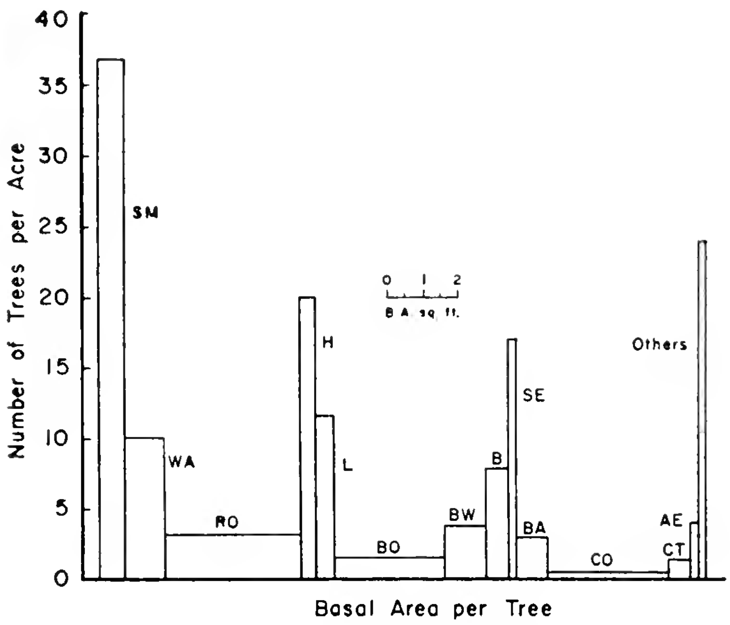

FIGURE 2. — Number of Trees Per Acre and Average Basal Area Per Tree.

(See Table 2 for explanation of species symbol.)

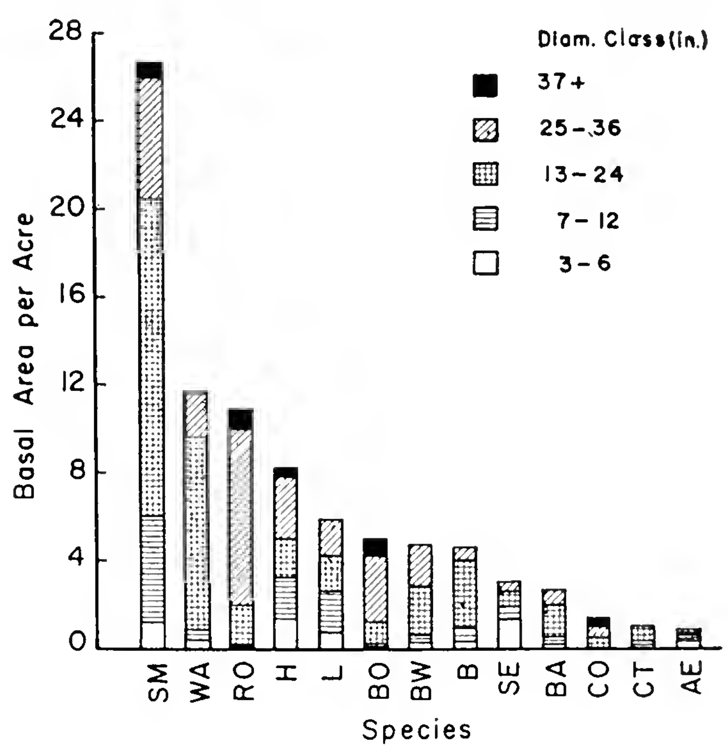

FIGURE 3. — Basal Area Per Acre by Species and Diameter Class.

broad diameter classes are shown for the various species.

Sugar maple is the leading species in the woodland, comprising one-fourth of the total number of trees and slightly less than one-third of the stand basal area. It is well represented throughout the stand with frequencies ranging from 41 percent for the 1- and 2-inch diameter classes to 96 percent for the larger trees. The high frequency of the latter is probably related to the relatively large block size (0.619 acre) used in the survey. The density of maple varied considerably throughout the woodland. On plots where is occurs, the IVI (which combined both relative density and relative basal area) ranged from 1 to 149 (maximum possible value, 200) with an average of 54.91. This value was more than twice as great as the value for the nearest competitor.

Hackberry ranks second in importance and is particularly prevalent in the 3- to 6-inch diameter class. Here it almost equals sugar maple in the number of trees per acre. It also has a frequency of 96 percent. Although there are a number of large hackberry scattered throughout the stand, the average diameter of 8.6 inches reflects the preponderance of small trees. These are fairly well distributed throughout the woodland.

The importance of the oaks is chiefly due to the large size of individual trees. Average diameters are 23.9, 25.1, and 27.1 inches, respectively, for bur oak, chinquapin oak, and red oak. The largest tree in the woodland is a 48-inch bur oak.

White ash and basswood, ranking third and fifth in Importance Value, are well distributed throughout the stand with frequencies of 96 and 85 percent. White ash has an average diameter of 14.3 inches compared with 9.6 inches for basswood. Basswood, however, is better represented in the smaller diameter classes but is reproducing very poorly compared to white ash.

Slippery elm, although ranking fourth in Importance Value, is largely present among the smaller diameter classes. It equals maple in the number of trees present in the 3- to 6-inch class and is well distributed throughout the stand.

The relative importance of the seven leading species can be illustrated by considering the number of blocks on which each species was the leading dominant (highest IVI), or ranked second, third, and fourth or less in Importance Value (Table 4).

Table 4.—Importance Value Index, by Numbers of Blocks for Seven Leading Species.

Species	IVI rank			
	1st	2nd	3rd	4th and below
	Number of blocks			
SM	55	17	6	14
H	15	15	11	52
WA	6	21	20	45
SE	3	7	18	63
L	7	9	7	59
RO	3	15	8	41
B	2	3	7	76

The relatively dense understory is dominated by pawpaw and spicebush, along with saplings of the various trees species. Pawpaw grows to a larger size than spice-bush, and its 480 stems per acre in the 1- and 2-inch diameter classes are almost as many as all other species combined. It also occurred on 55 percent of the 384 1/100-acre quadrats. Reproduction of both pawpaw and spice-bush is relatively heavy (682 and 702 per acre) and is exceeded only by sugar maple.

While the herbaceous plants were not included in this study, observations have shown that the early spring flora is dominated by trillium (*Trillium recurvatum*), Dutchman's breeches (*Dicentra cucullaria*), wild geranium (*Geranium maculatum*), blue phlox (*Phlox divaricata*), while wild ginger (*Asarum canadense*), water-leaf (*Hydrophylum spp.*), and May apple (*Podophyllum peltatum*) appear later. The summer season is characterized by the obnoxious woods nettle (*Laportea canadensis*) with some touch-me-nots (*Impatiens pallida* and *I. biflora*). The tall bell-flower (*Campanula americana*), along with white snake-root (*Eupatorium rugosum*) and various other Compositae, are most prominent in the late summer and fall.

Changes in Composition

The large number of dead elm is the most striking feature of the present stand and has resulted in significant changes in stand composition. This catastrophic mortality, amounting to 1,585 trees in the entire woodland, began about 15 years ago. It resulted from the combined effects of phloem necrosis and the Dutch elm disease. The number of dead trees per acre for all species combined and for elm are shown in Table 5.

Total mortality of all species other than elm was less than 5 trees per acre. Since both dead-standing and dead-down trees were tallied, the period covered by the mortality figures is probably 10 to 15 years. The magnitude of the mortality is emphasized by the fact that there is more than half as much area in dead trees as in living trees. All this has happened in a woodland that was completely protected from fire and grazing and that had a minimum amount of use and disturbance by man for a period of 45 years.

The proportion of sugar maple to elm appeared to change between

TABLE 5.—Mortality of Elm and all Species Combined.

	Diameter class, inches											
	3-6		6-12		12-24		24-36		36+		Total	
	All	Elm	All	Elm	All	Elm	All	Elm	All	Elm	All	Elm
Number of trees per acre..	7.8	6.8	6.9	5.8	12.7	10.8	4.3	3.8	0.4	0.4	32.1	27.6
Basal area, sq. ft. per acre.	0.8	0.7	3.8	3.2	23.6	20.3	19.5	17.4	3.8	3.3	51.5	44.9

TABLE 6.—Number of Maple and Elm in 1922, 1935, and 1940.

Year	Number of trees per acre				Source
	SM	AE	SE	Total elm	
1922.......	33	35	....	35	McDougall (1922)
1935.......	36.5	15.7	11.9	27.6	Marberry (1936)
1940.......	39.2	16.0	8.8	24.8	Vestal and Heermans (1945)

1922 and 1940 as shown in Table 6. McDougall (1922) did not mention the occurrence of slippery elm in the woodland. There is a possibility that it was included with American elm. The average diameter of 15.8 inches for slippery elm, calculated from the data of Vestal and Heermans (1945), lends some support to this idea. The figures given in Table 6 should be used with caution for reasons given in the review of past work. However, the proportion of maple to elm is probably a fairly true representation of stand composition. Differences in the 1935 and 1940 data are probably due to sample size and sampling techniques rather than any perceptible change during this relatively short period.

Some idea of composition changes between 1940 and the present can be gained by comparing the data of Vestal and Heermans (1945) with those of the current survey (Table 7).

The most obvious changes are the decrease in American elm, an increase in the number of slippery elm with a decided shift from large to small trees, and a substantial in-

TABLE 7.—Number of Trees and Basal Area Per Acre in 1940 and 1963.

Species	1940		1963	
	Number trees	Basal area	Number trees	Basal area
SM..................................	39.2	34.6	37.81	27.49
AE..................................	16.0	21.9	4.16	0.76
SE..................................	8.6	11.4	17.96	3.04
L..................................	10.4	11.6	11.99	6.01
WA..................................	9.4	8.5	10.38	12.01
B..................................	7.1	7.5	7.86	4.60
RO..................................	2.8	8.5	2.81	11.23
BA..................................	4.8	3.0	2.86	2.56
H..................................	4.1	3.1	20.90	8.47
BW..................................	3.0	5.5	3.96	4.93
BO..................................	1.5	3.5	1.61	5.01
CO..................................	1.2	2.2	0.40	1.38

crease in the number of hackberry. These increases are undoubtedly related to canopy openings created by elm mortality.

The number of sugar maple has not changed significantly. However, the decrease in basal area for this species between 1940 and 1963 is not realistic. Mortality of sugar maple, determined in the 1963 inventory, was only 1.4 square feet per acre. This is not a very large figure, particularly when spread over a period of 10 to 15 years. Thus, the apparent decline is unlikely and is probably related to the sampling bias that was weighted toward the south half of the woodland, where the concentration of maple was heaviest. Such bias would be more apparent in basal area than in tree numbers, since the former is a function of the square of the diameter. It is perhaps justifiable to assume that both the estimates of maple numbers and basal area in 1940 were too high. Certainly there is no other reason to believe that maple has decreased in the stand.

The proportion of maple in the north half of the woodland has changed from about one-fourth of the total in 1922 to 36.9 percent in 1963. However, areas shown onMcDougall's map (1922) as having little or no maple are still in the same condition. These are the low, poorly drained sites where the concentration of elm was greatest.

Future Composition

Based on the amount of reproduction, the number of saplings, and the diameter distribution of the larger stems, sugar maple should continue, or perhaps increase, its dominance in the stand. The number of sugar maple seedlings (2,450 per acre) is almost as great for all other species combined. Thus, the future population of this very tolerant species is already established and can take advantage of canopy openings that occur with the death of older trees. This gap phase replacement has been shown to be important in the maintenance of sugar maple as a major dominant in a maple-basswood forest in southeastern Minnesota (Bray, 1956). Maple may also become more important on the dead elm areas, particularly where the soils are not too poorly drained.

Red oak will continue to be an important stand component for a number of years. However, there are very few red oak trees under 13 inches in diameter, which means that replacement will be limited as mortality occurs in the larger diameter classes. While there were about 220 red oak "seedlings" per acre, these apparently rarely develop into saplings. Bray (1956) pointed out that red oak seedlings in a maple-basswood stand did not respond to canopy openings because of the rapid growth of sugar maple seedlings which quickly overtopped the slower growing oaks. The above comments also hold true for bur oak and chinquapin oak.

Hackberry, now second in over-all importance, may well maintain this position, since it is well represented in the smaller diameter classes, and large trees are scattered throughout the woodland. Hackberry reproduction is second to that of maple but tends to be clumped as indicated by its low (16 percent) frequency of occurrence. The same conditions hold for the 1- and 2-inch diameter classes.

The proportions of basswood, buckeye, white ash, black walnut, etc., appear to be relatively stable and are not likely to change barring some event that would seriously affect the maple population. All of these species are present in the smaller diameter classes. While there are few basswood seedlings, the capacity of this species to sprout following the death of parent trees is well known, and in this way it will remain an important stand component.

The future of the sites formerly occupied by pure stands of elm is uncertain at present. They are now dominated by spice-bush and pawpaw, of which there are 375 and 250 per acre in the 1- and 2-inch diameter classes. In contrast there are very few spice-bush on the mixed hardwood and maple sites, but the number of pawpaw is from two to three times greater on these than on the dead elm areas. Reproduction of overstory species is largely composed of sugar maple, hackberry, and white ash with some black walnut, buckeye, and slippery elm. However, there are more sugar maple saplings than of all these other species combined. The number of maple seedlings on the dead elm sites is almost equal to that on the mixed hardwood and about half that on the maple sites. More intensive studies of succession on the dead elm sites are now in progress.

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SELENOMONAS RUMINANTIUM, A BLOOD PARASITE OF WHITE-TAILED DEER IN ILLINOIS

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ABSTRACT. — *Selenomonas ruminantium* was found in 27 (6%) of 445 blood smears from white-tailed deer *Odocoileus virginianus* in Illinois. No other protozoan or helminth parasites were seen in these smears. The taxonomic position of *Selenomonas* is still uncertain. It has been considered a flagellate protozoon or a bacterium. Electron micrographs of sections of the flagella will probably be necessary to decide its position.

In conjunction with a study of disease of wild, whitetailed deer (*Odocoileus virginianus*) being carried out in Illinois under the direction of Dr. Deam H. Ferris, an opportunity was provided to study their blood parasites.

MATERIALS AND METHODS

The deer were shot by hunters in the October hunting seasons of 1958 thru 1962. They were brought to check stations maintained by the Illinois State Department of Conservation. There they were weighed and blood samples were taken for serologic studies. Blood smears were made of some of them and brought to the laboratory in Urbana for later parasitologic examination. The smears were fixed in methyl alcohol and stained with Giemsa stain. Each slide was carefully examined under the oil immersion objective, using a Leitz Ortholux microscope equipped with apochromatic objectives.

RESULT

The only blood parasite recognized was *Selenomonas ruminantium* (Certes, 1889) von Prowazek, 1913. Details of its occurrence are given in Table 1. The organism was found in 27 (6%) of 445 blood smears. It was present in 13 (8.5%) of 153 blood smears from northern Illinois (the Savanna Ordnance Depot and the vicinity of Oregon, Illinois), and in 14 (4.7%) of 292 blood smears from southern Illinois (the region around the Dixon Springs Experiment Station of the Uni-

TABLE 1.—Prevalence of *Selenomonas Ruminantium* in the Blood of White-tailed Deer *Odocoileus Virginianus* in Illinois.

Locality and year	No. smears Examined	Positive smears Number	Positive smears Percent
Savanna Ordnance Depot			
1958	52	2	4
Oregon, Illinois			
1958	101	11	11
Dixon Springs Exper. Sta.			
1958	100	9	9
1959	76	4	5
1961	111	1	1
1962	5	0	0
Total	445	27	6

versity of Illinois). Its prevalence varied from 1 to 9% in different years around the Dixon Springs station. Because of this variation, the difference in prevalence between northern and southern Illinois is not considered significant.

Taxonomy and Discussion

Selenomonas ruminantium occurs commonly in the rumen of cattle, sheep and goats; it has also been found in various wild ruminants including the gazelle, giraffe and antelope (*Cephalophus maxwelli*) in Africa and the pronghorn antelope (*Antilocapra americana*), mule deer (*Odocoileus hemionus*) and elk (*Cervus nannodes*) in the United States (California) (Levine, 1961). According to Lessel (1957), it is the predominant organism found on microscopic examination of the rumen fluid.

S. ruminantium has been found in the blood of *C. maxwelli* in Africa by Kérandel (1909), of *A. americana* in California by Chattin, Herman and Kirby (1944), and of *O. hemionus* in California by Herman and Sayama (1951). Ours is the first report of its occurrence in *O. virginianus*.

S. ruminantium is crescent-shaped, 8 to 11 by 2 to 3 μ, with a tuft of flagella arising from the center of the concave side. The nucleus is in the center of the concave side.

Three species of *Selenomonas* are presently accepted. *S. ruminantium* occurs in the rumen of various ruminants. *S. palpitans* Simons, 1922 occurs in the cecum and upper part of the colon of the guinea pig. *S. sputigena* (Flügge, 1886) Boskamp, 1922 occurs in the mouth of man. The last species was accepted as the type species of the genus by the Judicial Commission of the International Microbiological Congress (1958), altho Jeynes (1956) had previously considered *S. ruminantium* to be the type species.

The taxonomic position of the genus *Selenomonas* is still uncertain. Wenyon (1926) and Levine (1961) considered it a flagellate protozoon and assigned it to the family Callimastigidae. Jeynes (1955, 1956) also considered it a flagellate, assigning it to the family Monadidae.

However, Bryant (1956), Lessel (1957), and Hobson and Mann (1961) considered it to be a bacterium belonging to the family Spirillaceae. MacDonald, Madlener and Socransky (1959) considered *S. sputigena* and *S. ruminantium* to be bacteria, assigning them to the genus *Spirillum*, but they considered *S. palpitans* to be a protozoon.

The reasons for this difference of opinion are grounded in the structure and cultivability of the organisms. Macdonald (1953) cultivated *S. sputigena* readily in thioglycollate broth and other media; Macdonald and Madlener (1957) studied it further, isolating it from the oral cavity of man in veal heart infusion-sodium lauryl sulfate-sheep serum medium.

Bryant (1956) first cultivated *S. ruminantium* from bovine rumen contents, using a variety of anaerobic media, including rumen fluid or yeast extract-trypticase media containing glucose. Bryant (1956) described the cultural characters of *S. ruminantium* from cattle. Some strains are unable to utilize lactate, whereas others produce propionic and acetic acids from it; Bryant (1956) considered the latter a new variety, *S. ruminantium* var. *lactilyticas*.

Hobson and Mann (1961) considered *S. ruminantium* var. *lactilyticas* to be among the most important microorganisms of the glycerol-fermenting flora of the sheep rumen. They grew it anaerobically in a casein hydrolysate (Difco Casitone)-yeast extract medium containing ammonium sulfate and 1.0% glycerol; the glycerol was fermented to propionic acid. Later, Hobson, Mann and Smith (1963) found that Strain 6 of *S. ruminantium* from sheep differed from bovine *S. ruminantium* in not utilizing ammonia and in requiring amino acids for growth.

S. palpitans of the guinea pig has not been clutivated, and Macdonald, Madlener and Socransky (1959) reported that all their attempts to do so were unsuccessful.

The appearance of *S. ruminantium* in culture is different from its appearance in the rumen. The selenomonads from sheep studied by Hobson and Mann (1961) in culture were curved gram negative rods with flagella in various locations, especially on the middle of the curved side. They gave outline sketches of 15 individuals, but none had the crescent shape characteristic of the species, and all were smaller than the forms present in the rumen. However, Hobson, Mann and Smith (1962) found that fluorescent antisera prepared against strains of the small *S. ruminantium* var. *lactilyticas* grown in vitro from sheep rumen contents appeared to react specifically with some of the large selenomonads that they saw in vivo in rumen contents; they concluded that the selenomonads isolated in culture were probably the same as those seen in the rumen.

Macdonald, Madlener and Socransky (1959) published three electron micrographs of *S. sputigena* shadowed with palladium and another one unshadowed, and said that *S. ruminantium* appeared similar. They stated that the flagella of these two species originated in a random fashion, singly or as tufts, from any point on the circumference of the body. However, their electron micrographs did not reveal the structure of the flagella. As mentioned above, they considered these two species to be bacteria, and *S. palpitans* to be a protozoon.

On the basis of the above studies, it is still uncertain whether *Selenomonas* is a protozoon or a bacterium. The fact that *S. ruminantium* will grow in bacterial culture media does not prove that it is a bacterium; trichomonads, for instance, will grow readily in thioglycollate broth and other bacterial media, and trypanosomes will grow readily in leptospire media. Electron micrographs of sections of the flagella prepared to establish their fine structure will probably be necessary to decide the taxonomic position of the genus.

There is still some uncertainty whether a parasite of the rumen and reticulum can also occur in the blood or whether it may have invaded the blood stream after death or may have been introduced into the smears as a contaminant at the time they were prepared. The last possibility seems unlikely to have occurred in such a high percentage of cases, especially since care was taken to avoid such contamination. However, since all the smears examined in the present study were made after the animals had died, the second possibility cannot be ruled out. Positive smears from the peripheral blood of living animals would be required in order to do so. In discussing the possibility, however, Herman and Sayama (1951) considered it unlikely.

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NEWS AND COMMENTS

This issue brings to you the second set of "Notes". In order to get the section going I have utilized some rather long papers with Tables and Figures. However, I hope this practice does not become a regular part of the format.

Stover Herbarium of Eastern Illinois University.—On June 8, 1963, the Botany Department adopted the following resolution unanimously and with enthusiasm:

> Whereas Dr. Ernest L. Stover spent nearly forty years collecting, pressing, mounting and identifying plants of East Central Illinois for the herbarium of Eastern Illinois University, it is only fitting and proper that this teaching collection of plants, that will be used by many generations of students yet to come to Eastern, be named the Stover Herbarium.

The Eastern Illinois University Botany Department has had strong leadership over the years with internationally known men serving Botany; Otis William Caldwell, 1899 to 1907; Edgar Nelson Transeau, 1907 to 1915; and Arthur G. Vestal, 1915 to 1920. Dr. Ernest L. Stover was no exception to the pattern established by his predecessors when he assumed the headship in 1923 and served faithfully and with honor through 1960. On September 27, 1963 a new Life Science Building was dedicated at Eastern Illinois University and it was at this time that the Stover Herbarium was officially recognized and dedicated.

Dr. John W. Voigt, Executive Officer of the General Studies Program at Southern Illinois University and one of the many students of Dr. Stover pays this tribute:

ERNEST LINCOLN STOVER

> "Former students would each have their own way of paying tribute to Dr. Stover, but the essence of their remarks would surely suggest that it was their good fortune to come in contact with him in the teacher-student relationship.
>
> A hallmark of Dr. Stover's teaching has been his way of bringing out the best in a student. It was through his inspiration, challenge, and careful nurture of their academic growth and excellence that his students often went on to further study in the discipline he represented. Dr. Stover earned the respect and complete devotion of his students. A big reason for so many of his students going on to advanced study and reaching high attainment was no doubt motivated by the student not wishing to disappoint this enthused and lovable master.
>
> It is altogether fitting that Eastern Illinois University should designate space in its new Life Science Building as the Stover Herbarium. Dr. Stover has richly contributed to the excellence of botanical teaching and study which has been a tradition at Eastern since its beginning."

A living tribute to the influence of Dr. E. L. Stover on his students is reflected in the great number of advanced degrees earned by them. Over eighty of his students have been granted Master's degrees. More than thirty Eastern Illinois University Botany students have received the doctorate.

With the retirement of Dr. Stover, the Herbarium was entrusted to Dr. John E. Ebinger, a taxonomist trained at Yale University. Dr. Ebinger received his B. S. from Miami University, Oxford, Ohio, in 1955; M. S. and Ph. D. degrees from Yale University in 1959 and 1961, respectively. During 1961-62 he worked on the application of data processing to taxonomy for the Connecticut Agricultural Station at

New Haven, Connecticut. Following a year of teaching at Roanoke College at Salem, Virginia, Dr. Ebinger joined the Botany faculty at Eastern Illinois University.

Several people have contributed plants to the Eastern Illinois University over the years. In addition to Stover, the names of Caldwell, Cooper, Transeau, Sampson and Sargent are found commonly on the older specimens.

A check list of the plants of Coles County was maintained over the years by Professor Stover. In addition, Dr. H. F. Thut, with the assistance of students, completed a flora of the vascular plants of Fox Ridge State Park which is located in Coles County near Charleston, Illinois. These specimens along with several other student collections have been deposited in the Stover Herbarium. A recent inventory indicates that the herbarium contains well over 6,000 specimens of vascular plants. The species represent over 450 genera in 127 different families. In addition, there are about 1,000 specimens in the Ecological Herbarium and many specimens of the lower plant groups represented mainly by mosses and fungi.

Dr. Ebinger has added many plants to the Herbarium in his first year and is encouraging an exchange system of specimens. We at Eastern are proud of his accomplishments in organizing and expanding the Stover Herbarium. We introduce him to you, the Botanists of Illinois, and encourage the taxonomists to contact him on any mutual problems that you might have.

Professor Alden Cutshall, Head of the Department of Geography, Chicago Undergraduate Division of the University of Illinois responded to my "gentle threat" with the following news.

In preparation for the move to the new campus at Chicago Circle, the Chicago Undergraduate Division of the University of Illinois has changed from a divisional organization to a traditional departmental arrangement. The recently appointed department heads of the science departments and their most recent affiliations are as follows. Except as indicated, all appointments were effective September 1, 1964.

- Biology, John E. Corliss, Illinois, Urbana
- Chemistry, William Sager, George Washington Univ. (effective February 1, 1965)
- Geography, Alden Cutshall, Illinois, Chicago
- Geology, Frederick E. Kuellmer, New Mexico Institute of Mining and Technology
- Psychology, I. E. Farber, State University of Iowa
- Physics, Lester Winsberg, Illinois, Chicago and Argonne Laboratory

Who would like to be an Associate Editor in Botany? Someone offered to take the job last April, but I lost their name.

NOTES

A DEVICE FOR AUTOMATICALLY FEEDING AND COLLECTING THE FECES OF SMALL MAMMALS

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Abstract. — An automatic device was designed to feed two caged cottontail rabbits and collect fecal pellets hourly.

Automation in feeding and collecting pellets at hourly intervals facilitates the study of periodic activity and of correlations between foods eaten and fecal pellets deposited. The electrical drive of this feed-fecal machine was perfected by the Central Research Shop, Southern Illinois University. Total cost of construction of the automatic device was approximately $81; $42 for the mechanical part and $39 for the electrical part, not including labor or cages. Although designed for use with wild cottontail rabbits, with slight modifications in type of cage and size of turntables and cups, the apparatus could be used successfully with rodents and other mammals. With smaller animals and using smaller cups, a 24-hour wheel could be constructed thus eliminating the checking of the machine more than once a day.

Mechanical Construction

Two metal animal cages, 14 inches wide, 14 inches deep, and 24 inches long, are suspended from the top crossbars of a wooden framework (Figs. 1a and 1b). The cages (C) have solid walls and wire mesh floors and doors. In the rear corner of the floor of each cage (Fig. 1c), there is an opening (FO) of slightly less diameter than the 3-inch feed cup (FdC). The feed cups pass within ⅛ inch of the floor of the cage. A rubberized canvas funnel (F) extends from the floor of each cage to a cup (FcC) which collects the fecal material. Rubberized canvas prevents adherence of fecal pellets. Collars (FuC) hold the terminal ends of the funnels over the cups which collect the fecal pellets.

Movement of the feed cups to a position below the floor openings is by a turntable (FDW, Fig. 1c); movement of the fecal cups beneath the ends of the funnels is by a separate turntable (FBW). Each turntable is of sufficient diameter to arrange two rows of cups on it; the inner row of cups services one cage, and the outer row the other cage. Each row consists of 12 cups, one for each hour. Thus, rabbits are disturbed only when checked at 12-hour intervals. A small metal funnel in each fecal cup prevents droppings from bouncing out. Cups made from cardboard coin tubes with metal ends, provided by the R. C. Can Company of St. Louis, Missouri, were used successfully.

The shaft (S) of each turntable is a ½-inch metal pipe. The lower end of the shaft rotates on a large ball-bearing fitted into a machined concavity. The shafts are held vertical by wooden crossbars. A bicycle chain (CD) connects two sprockets, one on each shaft, forming an inter-shaft chain drive and allowing for the synchronization of movements of both turntables (Fig. 1c).

The rabbit can feed from only the cup in position below the floor of the cage. A new cup is in position each hour and at the same time a new cup is in position for the collection of fecal pellets on the turntable below the cage.

Electrical Drive

The apparatus is driven electrically (115 volts, A. C.) as illustrated in the wiring diagram (Fig. 1d). Each hour a timer motor (TM) (one revolution per hour) closes a timer switch (TS) which applies voltage to a clutch solenoid (CS) for two to four seconds. The clutch solenoid energizes the brake solenoid (BS), brake motor switch (BMS), and the drive motor (DM). The energized brake solenoid withdraws the projectile (P, Fig. 1d), freeing the lower turntable holding the fecal cups. The drive-shaft of the drive motor makes contact with the upper turntable (food cups) which is edged in emery cloth. The turntables, connected by sprockets and chain, commence the cycle of rotation. The rotation of the lower turntable breaks contact between the positioning cam (PC, Fig. 1a) and the stop switch (SS, Fig.

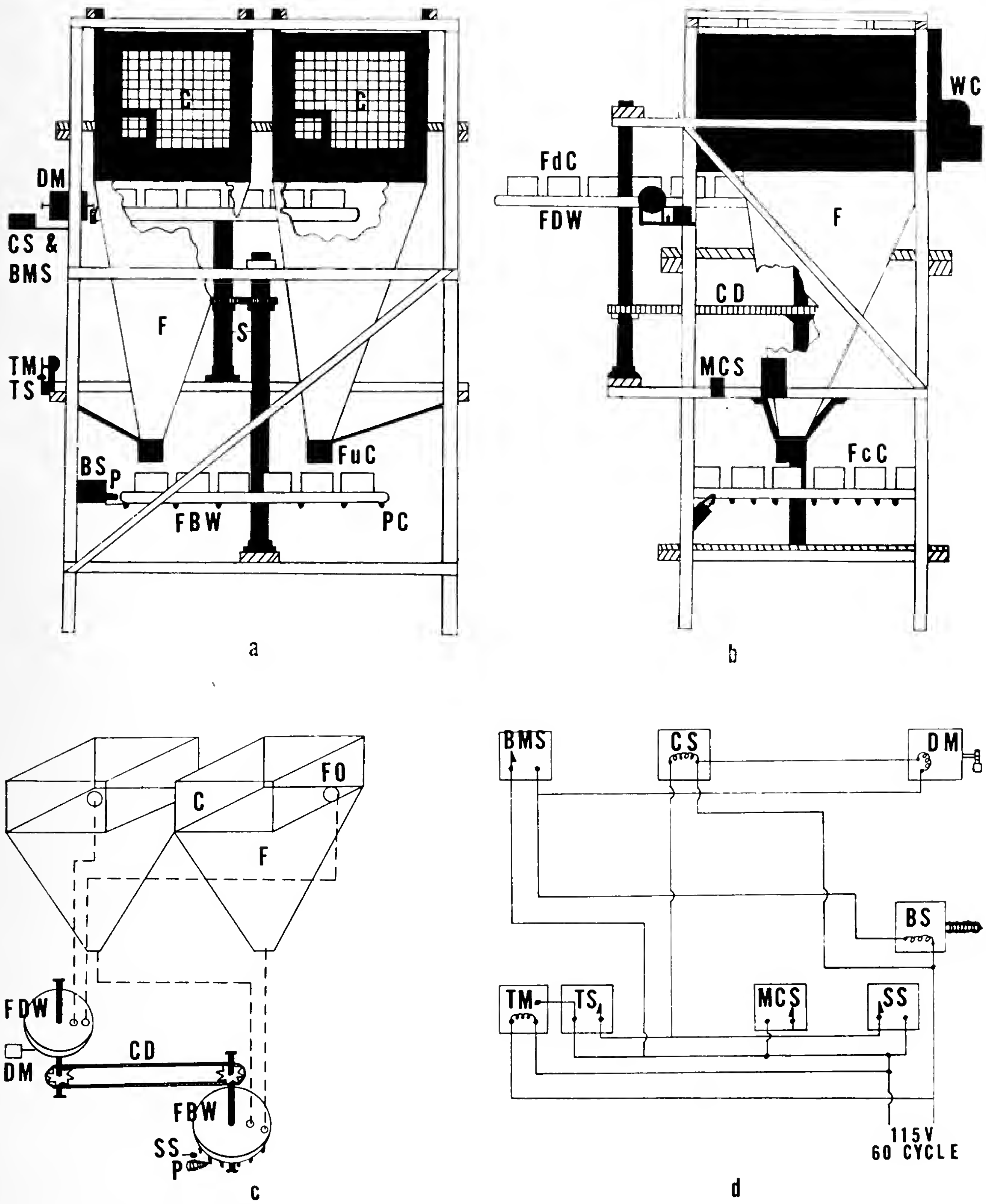

FIGURE 1. — Diagram of automatic feed-fecal device showing a. front view; b. view from left side; c. details of mechanical construction; and flow of d. electrical circuit. Letter symbols used are: C, cage; F, funnel; P, projectile; S, shaft; BS, brake solenoid; CD, chain drive; CS, clutch solenoid; DM, drive motor; FO, food opening; BMS, brake motor switch; FBW, fecal brake wheel; FcC, fecal cup; FdC, feed cup; FDW, feed drive wheel; FuC, funnel collar; MCS, manual cycle switch; PC, positioning cam; SS, stop switch; TM, timer motor; TS, timer switch; WC, water container.

1c). The loss of contact causes the stop switch to open. The lower turntable rotates until the stop switch comes into contact with the next positioning cam which again closes the stop switch, de-energizing the clutch solenoid, brake solenoid, and brake motor switch thus stopping the motor and the lower turntable. The lower turntable is stopped in position by the de-energized brake solenoid and subsequent release of the projectile (known commercially as a spring-loaded out solenoid) against the turntable. Thus, the upper turntable functions in activation of the cup movement and the lower turntable functions in deactivation of the cycle. The intershaft chain drive coordinates the reciprocal reactions. A manual cycle switch (MCS, Fig. 1b) was inserted for convenience in checking the feed and fecal cups.

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NON-FUNCTIONAL INGUINAL MAMMAE IN A LACTATING NORTH AMERICAN BADGER

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ABSTRACT. — A lactating female badger (*Taxidea taxus*) collected in Carroll County, Illinois had six functional mammae.

The female North American badger, *Taxidea taxus*, posseses eight mammae. A lactating female badger (Univ. Illinois 29676) that was killed May 25, 1962, at four miles northeast of Chadwick, Carroll County, Illinois, has been preserved frozen until the spring of 1964, at which time I skinned and dissected the carcass. This badger in life had six normally functioning mammae, but its inguinal pair was non-functional. Each inguinal mamma was abnormally small and non-pigmented, and its nipple or teat was hardly protuberant. Furthermore, no lactiferous tissue was noticed underlying the inguinal mammae, whereas large masses of it were found beneath the skin of the large, dark normal mammae.

The length of each nipple, measured on the fresh, moist skin in order from the inguinal one on the right side, was 3 mm. (inguinal), 7, 8, and 7. The approximate diameters of the mammae, measured in the same manner, were 5 mm. (inguinal), 42, 43, and 45.

Non-functional mammae in *Taxidea* have never been reported, and I can report nothing concerning their origin or frequency in nature. A lactating female (Univ. Illinois 14369) from three miles north and one mile west of St. Joseph, Champaign County, Illinois, killed March 9, 1956, and another (Univ. Illinois 15179) from 6½ miles north and one mile west of St. Joseph, killed November 25, 1956 (both are tanned skins) are characterized by abdominal and pectoral mammae slightly larger than their inguinal mammae. A lactating female (Univ. Illinois 1025) killed June 8, 1949, eight miles east of Canton, Illinois, definitely had possessed eight functioning mammae.

The abnormal badger is adult, showing moderate wear on its molars, marked wear on its canines, and fusion of the nasal sutures. It was probably in its second or third year of life. No placental scars were evident in the uterus, indicating that birth of young had not recently occurred.

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MODIFICATION OF THE KAPLAN SHAKE APPARATUS FOR ALGAL GROWTH

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ABSTRACT. — The design of an illuminated shake culture apparatus for algal growth studies is described. Growth of *Chlorella pyrenoidosa* is uniform in all shaker positions and is linear with time.

The Kaplan shake apparatus (Kaplan, 1956) originally designed for fungal studies, was modified to provide an illuminated shake unit suitable for studies of algal growth. Such a unit is satisfactory for instructional use in the laboratory where less-carefully-controlled conditions prevail.

A unit (Fig. 1) was built to provide the rotary motion found in the Kaplan shake apparatus but was modified to include a second, easily removable platform as well as an illuminator. This permits the use of platforms having holders for flasks of various sizes (48

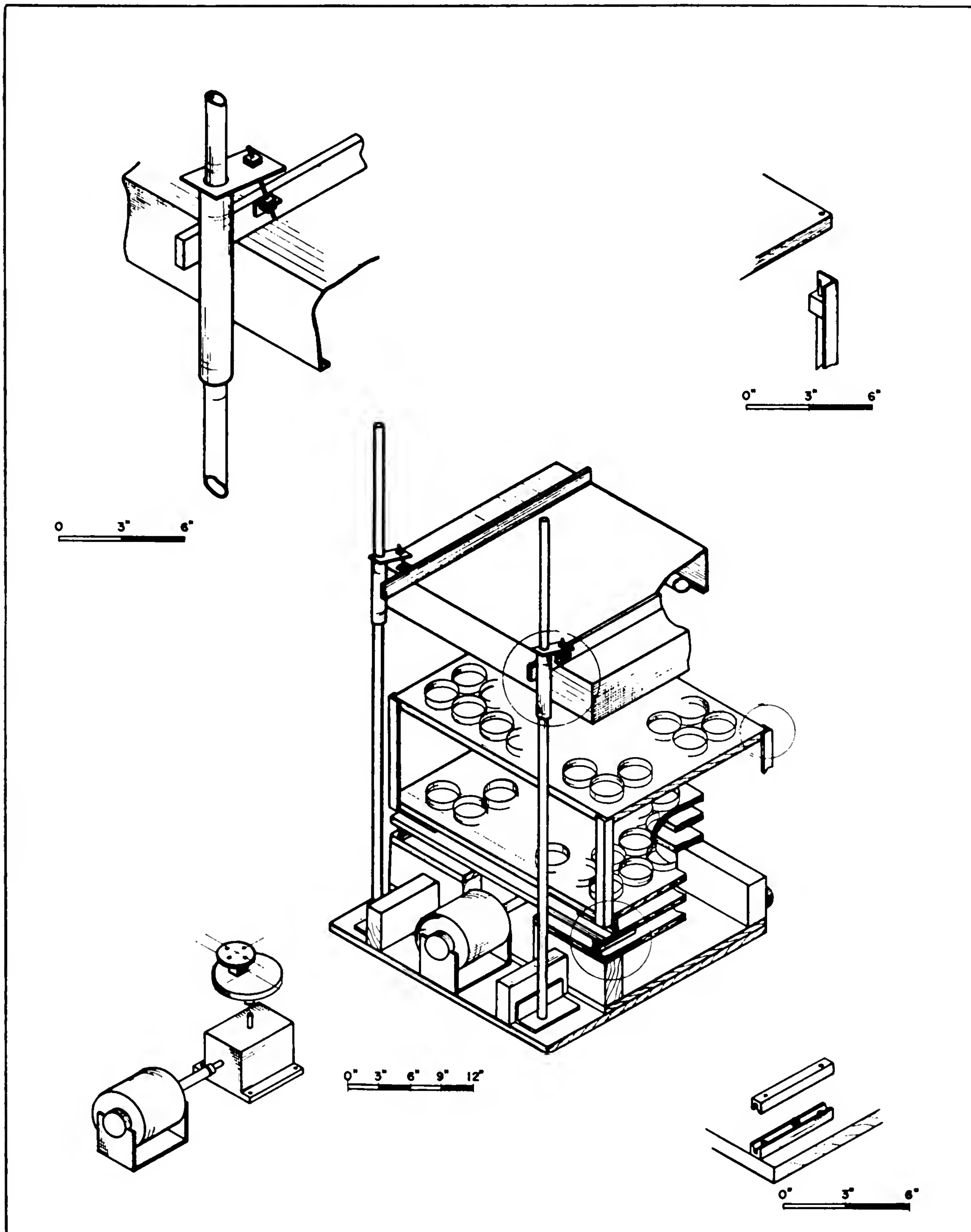

FIGURE 1. — Diagram of the modified Kaplan shake apparatus. The apparatus shown is equipped with platforms each having a capacity of 48 125-ml Erlenmeyer flasks. Center, rear view of the apparatus; upper left, detail of the method used to hold, and to raise and lower the illuminator; upper right, detail for mounting upper platform; lower left, detail of the drive mechanism; and lower right, detail of channels with ball bearings.

holders for 125 ml Erlenmeyer flasks). The illuminator is adjustable with respect to height above the level of the culture flasks. In this way, addition or removal of culture flasks is facilitated. Raising or lowering the illuminator controls the light intensity. Light is provided by four Gro-lux fluorescent tubes wired in parallel. When the lamps are 7 inches above the platform, the light intensity varies from about 200 foot candles at the outer edges and corners to 300 foot candles in the center of the platform. The apparatus is powered with a ¼ hp motor and the speed (110 rpm) is maintained with a gear-box.

This shake culture apparatus has been employed in studies of growth of the green algae *Chlorella pyrenoidosa*. When grown on modified Chu medium (Gerloff et al., 1952), the algal cultures attained a dry weight of about 15 mg per 50 ml of nutrient medium in 4 days. Growth was linearly related to time. Growth, in terms of dry weight yield, was uniform in flasks whether they were in the center of the illuminated platform or at the edge, indicating that variation in incident light was not limiting growth.

Acknowledgment. This work was supported in part by National Science Foundation Grant GB-1072.

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A CORVID FROM THE MIOCENE OF COLORADO

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ABSTRACT. — Corvid sp. is reported from the upper Miocene beds of northeastern Colorado.

To my knowledge, corvids have not been reported from the Tertiary deposits of North America. Consequently, I consider it to be of interest and importance to record the discovery of a specimen of Miocene age in northeastern Colorado. The specimen was found in the lower part of the Pawnee Creek formation associated with the Kennesaw local fauna of upper Miocene age, in the SE¼ of sec. 26, T12N., R55W., Logan County, Colorado. For a detailed account of these deposits see E. C. Galbreath (A Contribution to the Tertiary geology and paleontology of northeastern Colorado. Univ. Kansas Paleont. Contrib., Vertebrata No. 4, pp. 1-120, pls. 1-2, figs. 1-26; March 15, 1953).

The new material, the distal end of a right humerus (Southern Illinois University Zoology Department No. P 198), may be best designated as Corvid sp. In size (8.8 mm. in diameter) the fragment is comparable to the humeri of males of *Nucifraga columbiana* from Crater Lake National Park, Klamath County, Oregon. Comparison of this specimen with the humerus of individuals of several species of corvids shows structural differences.

The value of this discovery lies in demonstrating that at least one kind of corvid was present in North America as early as late Miocene times.

Manuscript received June 29, 1964.

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